Instruction Manual

GENERAL RADIO
Custom-Products Operation

OPERATING INSTRUCTIONS

TYPE 2990-9390

AUTOMATIC IMPEDANCE-MEASURING SYSTEM

Form 2990-9390
April, 1973
GKR

General Radio

300 BAKER AVENUE, CONCORD, MASSACHUSETTS 01742
Telephones: 617/369-8770 (Concord) • 646-7409 (Boston)
TWX: 710 347-1051 • Telex: 94-594

MARKETING

OPERATING INSTRUCTIONS

TYPE 2990-9390

AUTOMATIC IMPEDANCE-MEASURING SYSTEM

1.1 INTRODUCTION

The Type 2990-9390 Automatic Impedance-Measuring System consists of a standard Type 1683-9742 Atuomatic RLC Bridge and a Type 1783-9003 Digital Limit Comparator connected with a 4025-1200 Cable. A 1683-P1 Test Fixuture is also included with the system. The bridge will make measurements of capacitance and dissipation factor or inductance and resistance, and compare the measured data to values set on the Digital Limit Comparator.

2.1 OPERATION

2.1.1 General

The various controls of the 1683 and 1783 are identified in their respective instruction manuals. The operation of the system is described in the following paragraphs. System components are listed on Drawing 2990-9390-0L.

2.1.2 RLC Bridge

The 1683 Automatic RLC Bridge contains Option 5B (High-Level Data Output), Option 2 (Remote Programmability) and Option 3 (Leakage Current Measurement Capability). The High-level data output is necessary to interface with the 1783 comparator. The Leakage Current Option allows GO/NO-GO measurements of capacitor leakage current to be made concurrent with a capacitance measurement. The remote programmability option provides for remote control of all bridge measurement functions.

2.1.3 Limit Comparator

The 1783 Comparator has go, no-go indicator lights that are controlled by the limit settings in the 5-digit A and B UPPER and LOWER LIMIT controls on the front panel. The A UPPER and A LOWER LIMIT controls should be set for the limit values of C or L depending upon which measurement is being made, C_SD or L_SR_S. The B UPPER and B LOWER LIMIT controls should be set for the limit values of D or R depending upon which measurement is being made, C_SD or L_SR_S.

2.1.4 System Operation

The system should be operated as follows:

a. Connect the 4205-1200 Cable between the 1683 DATA OUTPUT and the 1783 BCD DATA INPUT connectors (Drawing 2990-9390-1D).

b. Set the controls on the 1683 front panel to the desired positions as determined from the 1683 Instruction Manual. The RANGE control should be set to the range in which the measurements are to be made.

c. Set the limits for the measurements on the 1783 according to paragraph 2.1.3. The limits must be set between 00000 and 19999 for the 1683 RANGE selected.

d. Connect the 1683-P1 Test Fixture to the 1683 Bridge.

e. Set the POWER-OFF switches for both the 1683 and 1783 to POWER.

f. Place a component in the test fixture and observe the measurement. The appropriate GO, NO-GO lights on the 1783 Comparator will be lit, the value of the measurement will be displayed on the 1683 Bridge. If the selected bridge range is too high for the unknown, the bridge display will read 00000, indicating the component value is on a lower bridge range. If the selected bridge range is too low for the unknown, the bridge display will read 19999, indicating the component value is on a higher bridge range. In either case the component should be rejected; however, if a measurement is desired, set the bridge to a range that will produce a measurement value. The bridge will attempt another measurement after 2.5 s.

g. Disconnect the component from the test fixture. Repeat step f for other components of the same relative value. Repeat steps b, c, and f for components of various values.

3.1 SERVICE AND MAINTENANCE

Should the system malfunction, isolate the fault to either the 1683 or the 1783 and refer to their instruction manuals.

General Radio

300 BAKER AVENUE, CONCORD, MASSACHUSETTS 01742
Telephones: 617/369-8770 (Concord) • 646-7409 (Boston)
TWX: 710 347-1051 • Telex: 94-594

MARKETING

SYSTEM WARRANTY

We warrant that this system is free from defects in material and workmanship and when properly used, it will perform in accordance with applicable specifications for a period of ninety days after original shipment. Any system that is found within the ninety-day period not to meet these standards, after examination by our factory, Regional Office, or authorized repair personnel, will be repaired or, at our option, replaced without charge.

The several instruments in this system have individual warranties. Those manufactured by General Radio Company are warranted for a period of two years after original shipment. Those not manufactured by General Radio Company have the warranty provided by the manufacturer.

OUR LIABILITY IS LIMITED TO THE ABOVE WARRANTY OF REPAIR OR REPLACEMENT OF THE SYSTEM AND SPECIFICALLY EXCLUDES ANY LIABILITY FOR CONSEQUENTIAL DAMAGES ARISING OUT OF FAILURE OF THE SYSTEM.

SERVICE

The warranty attests to the quality of materials and workmanship in our products. When difficulties occur which cannot be corrected using the service instructions, write or telephone the nearest General Radio service department giving full information concerning the difficulty.

Upon evaluation of this information, our Service personnel will recommend field servicing or the return of the equipment to General Radio Company for repair.

If the equipment must be returned, the Service Department will issue a Return Material Tag to insure proper handling and identification. If the warranty has expired, a purchase order should be forwarded to avoid unnecessary delay.

Form 1783-9003
April, 1973
GKR

General Radio

300 BAKER AVENUE, CONCORD, MASSACHUSETTS 01742
Telephones: 617/369-8770 (Concord) • 646-7409 (Boston)
TWX: 710 347-1051 • Telex: 94-594

MARKETING

OPERATING INSTRUCTIONS

TYPE 1783-9003

DIGITAL LIMIT COMPARATOR

The Type 1783-9003 Digital Limit Comparator is a standard 1783 Comparator, in a bench type cabinet with a 4205-1200 Cable (Drawing No. 1783-9003-0L), modified to operate with various limits of C, R and L. A 1781-4500 Format and Program Circuit Assembly has been substituted for the 1783-4710 Assembly and Switch Assembly S0901, A, B, C and D, 1783, has replaced the 1783-2000 Assembly.

Also, the front panel has been modified so that the switches read in general terms as follows:

A UPPER LIMIT
A LOWER LIMIT
B UPPER LIMIT
B LOWER LIMIT

All output data is in 1-2-4-8 BCD format.

SYSCON LISTING

GENERAL

SYSCON (System Connection) is a computerized method of documenting system cable and wire runs. The listings are in different groups for ease in locating a particular run. These groups include: a signal function index, a point-to-point wiring list, and an instrument connections list. Use of these lists will simplify troubleshooting and tracing signal paths between the various system units.

DESCRIPTION

In SYSCON convention each instrument, cable, and signal has a unique identification. Each instrument is identified by a single letter*, Cables are identified with the same letters that specify the instruments the cable connects to i.e., AC defines a cable between instrument A and instrument C. If more than one cable connects a pair of instruments, two letters and a numeral are used i.e., AC1, AC2, AC3. Signal names that are followed by an asterisk (*) indicate negative logic signals.

The system block diagram and/or the system interconnection diagram shows the letter designation, the General Radio "four-by-four" number (Part No.) and the noun name of each unit in the system. Figure I is a hypothetical example of a system illustrating the letter/number designations.

Signal Function Index - This list defines the function of each signal name in alpha-numberic order.

Point-To-Point Wiring - This list contains the signal point-to-point wiring connections in alpha-numeric order. The listing contains the source and destination socket and pin number information as shown in the following example:

			From			To	
Signal Name	Cable	Instrument	Socket	Pin	Instrument	Socket	Pin
AC03* BUS	CE	BRIDGE #2	J2	67	INTERFACE	E2	3

Instrument Connections List- This list has each instrument listed by its letter designation. Within each instrument list, the sockets are listed alpha-numerically. The wired signals at each socket are in no particular sequence.

Cable List- This list, not normally required by the user, lists the cable length and other cable information. When referred to in conjunction with a particular cable drawing, this list provides a manufacturing specification.

*In some large systems (more than 23 letter designations- A through Z except I, O, S) the single letters are followed by a character such as $, @, * or + as in A$, B$.

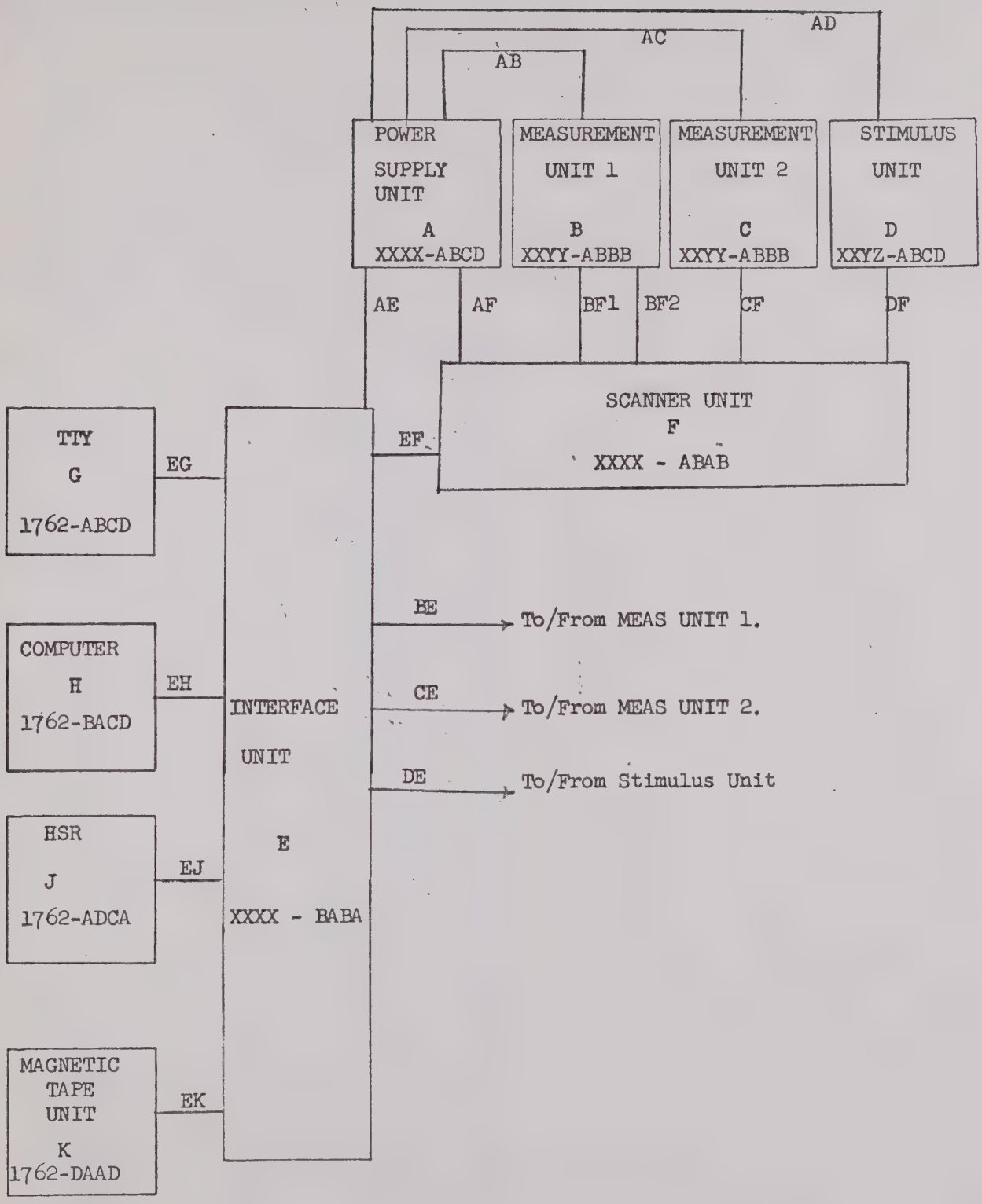


Figure I SYSCON Instrument and Cable Designations.

SIGNAL FUNCTION INDEX

2990-9390 AUTOMATIC IMPEDANCE MEASURING SYSTEM ISSUE NO.1 5-4-73

CABLE	SIGNAL NAME	FUNCTION
AB	BUSY/A	PRINT COMMAND
AB	COLOR/A	PRINTER COLOR SHIFT
AB	GND L&C2/A	GND/20000 L&C UNUSED
AB	GND L&C4/A	GND/40000 L&C UNUSED
AB	GND L&C8/A	GND/80000 L&C UNUSED
AB	GND R&D2/A	GND/20000 R&D UNUSED
AB	GND R&D4/A	GND/40000 R&D UNUSED
AB	GND R&D8/A	GND/80000 R&D UNUSED
AB	GNDCH/A	CHASSIS GROUND
AB	INHIBIT/B	INHIBIT BALANCE
AB	NI 0/A	L&C 10000 DATA LINE
AB	NI 1/A	L&C 8000 DATA LINE
AB	NI 2/A	L&C 4000 DATA LINE
AB	NI 3/A	L&C 2000 DATA LINE
AB	NI 4/A	L&C 1000 DATA LINE
AB	NI 5/A	L&C 800 DATA LINE
AB	NI 6/A	L&C 400 DATA LINE
AB	NI 7/A	L&C 200 DATA LINE
AB	NI 8/A	L&C 100 DATA LINE
AB	NI 9/A	L&C 80 DATA LINE
AB	NI10/A	L&C 40 DATA LINE
AB	NI11/A	L&C 20 DATA LINE
AB	NI12/A	L&C 10 DATA LINE
AB	NI13/A	L&C 8 DATA LINE
AB	NI14/A	L&C 4 DATA LINE
AB	NI15/A	L&C 2 DATA LINE
AB	NI16/A	L&C 1 DATA LINE
AB	NR 0/A	R&D 10000 DATA LINE
AB	NR 1/A	R&D 8000 DATA LINE
AB	NR 2/A	R&D 4000 DATA LINE
AB	NR 3/A	R&D 2000 DATA LINE
AB	NR 4/A	R&D 1000 DATA LINE
AB	NR 5/A	R&D 800 DATA LINE
AB	NR 6/A	R&D 400 DATA LINE
AB	NR 7/A	R&D 200 DATA LINE
AB	NR 8/A	R&D 100 DATA LINE
AB	NR 9/A	R&D 80 DATA LINE
AB	NRNG1/A	RANGE 1 DATA LINE
AB	NRNG2/A	RANGE 2 DATA LINE
AB	NRNG4/A	RANGE 4 DATA LINE
AB	NRNG8/A	RANGE 8 DATA LINE
AB	NR10/A	R&D 40 DATA LINE
AB	NR11/A	R&D 20 DATA LINE
AB	NR12/A	R&D 10 DATA LINE
AB	NR13/A	R&D 8 DATA LINE
AB	NR14/A	R&D 4 DATA LINE
AB	NR15/A	R&D 2 DATA LINE
AB	NR16/A	R&D 1 DATA LINE
AB	NVREF/A	+15V REF (50MA MAX)
AB	START/B	UNUSED START SIGNAL

POINT-TO-POINT WIRING

2990-9390 AUTOMATIC IMPEDANCE MEASURING SYSTEM — ISSUE NO.1 5-4-73

SIGNAL NAME	CABLE	FROM INSTRUMENT		SOCKET	PIN	TO INSTRUMENT		SOCKET	PIN
BUSY/A	AB	A	1683 BRIDG	DATAOUT	24	B	1783 DLC	SO30	A12
COLOR/A	AB	A	1683 BRIDG	DATAOUT	48	B	1783 DLC	SO30	E12
GND L&C2/A	AB	A	1683 BRIDG	DATAOUT	22	B	1783 DLC	SO30	D 1
GND L&C4/A	AB	A	1683 BRIDG	DATAOUT	46	B	1783 DLC	SO30	F 1
GND L&C8/A	AB	A	1683 BRIDG	DATAOUT	47	B	1783 DLC	SO30	H 1
GND R&D2/A	AB	A	1683 BRIDG	DATAOUT	12	B	1783 DLC	SO30	C 6
GND R&D4/A	AB	A	1683 BRIDG	DATAOUT	36	B	1783 DLC	SO30	E 6
GND R&D8/A	AB	A	1683 BRIDG	DATAOUT	37	B	1783 DLC	SO30	G 6
GNDCH/A	AB	A	1683 BRIDG	DATAOUT	50	B	1783 DLC	SO30	H13
INHIBIT/B	AB	B	1783 DLC	SO30	G12	A	1683 BRIDG	DATAOUT	23
NI 0/A	AB	A	1683 BRIDG	DATAOUT	21	B	1783 DLC	SO30	B 1
NI 1/A	AB	A	1683 BRIDG	DATAOUT	45	B	1783 DLC	SO30	G 2
NI 2/A	AB	A	1683 BRIDG	DATAOUT	44	B	1783 DLC	SO30	E 2
NI 3/A	AB	A	1683 BRIDG	DATAOUT	20	B	1783 DLC	SO30	C 2
NI 4/A	AB	A	1683 BRIDG	DATAOUT	19	B	1783 DLC	SO30	A 2
NI 5/A	AB	A	1683 BRIDG	DATAOUT	43	B	1783 DLC	SO30	H 3
NI 6/A	AB	A	1683 BRIDG	DATAOUT	42	B	1783 DLC	SO30	F 3
NI 7/A	AB	A	1683 BRIDG	DATAOUT	18	B	1783 DLC	SO30	D 3
NI 8/A	AB	A	1683 BRIDG	DATAOUT	17	B	1783 DLC	SO30	B 3
NI 9/A	AB	A	1683 BRIDG	DATAOUT	41	B	1783 DLC	SO30	G 4
NI10/A	AB	A	1683 BRIDG	DATAOUT	40	B	1783 DLC	SO30	E 4
NI11/A	AB	A	1683 BRIDG	DATAOUT	16	B	1783 DLC	SO30	C 4
NI12/A	AB	A	1683 BRIDG	DATAOUT	15	B	1783 DLC	SO30	A 4
NI13/A	AB	A	1683 BRIDG	DATAOUT	39	B	1783 DLC	SO30	H 5
NI14/A	AB	A	1683 BRIDG	DATAOUT	38	B	1783 DLC	SO30	F 5
NI15/A	AB	A	1683 BRIDG	DATAOUT	14	B	1783 DLC	SO30	D 5
NI16/A	AB	A	1683 BRIDG	DATAOUT	13	B	1783 DLC	SO30	B 5
NR 0/A	AB	A	1683 BRIDG	DATAOUT	11	B	1783 DLC	SO30	A 6
NR 1/A	AB	A	1683 BRIDG	DATAOUT	35	B	1783 DLC	SO30	H 7
NR 2/A	AB	A	1683 BRIDG	DATAOUT	34	B	1783 DLC	SO30	F 7
NR 3/A	AB	A	1683 BRIDG	DATAOUT	10	B	1783 DLC	SO30	D 7
NR 4/A	AB	A	1683 BRIDG	DATAOUT	9	B	1783 DLC	SO30	B 7
NR 5/A	AB	A	1683 BRIDG	DATAOUT	33	B	1783 DLC	SO30	G 8
NR 6/A	AB	A	1683 BRIDG	DATAOUT	32	B	1783 DLC	SO30	E 8
NR 7/A	AB	A	1683 BRIDG	DATAOUT	8	B	1783 DLC	SO30	C 8
NR 8/A	AB	A	1683 BRIDG	DATAOUT	7	B	1783 DLC	SO30	A 8
NR 9/A	AB	A	1683 BRIDG	DATAOUT	31	B	1783 DLC	SO30	H 9
NRNG1/A	AB	A	1683 BRIDG	DATAOUT	1	B	1783 DLC	SO30	B11
NRNG2/A	AB	A	1683 BRIDG	DATAOUT	2	B	1783 DLC	SO30	D11
NRNG4/A	AB	A	1683 BRIDG	DATAOUT	26	B	1783 DLC	SO30	F11
NRNG8/A	AB	A	1683 BRIDG	DATAOUT	27	B	1783 DLC	SO30	H11
NR10/A	AB	A	1683 BRIDG	DATAOUT	30	B	1783 DLC	SO30	F 9
NR11/A	AB	A	1683 BRIDG	DATAOUT	6	B	1783 DLC	SO30	D 9
NR12/A	AB	A	1683 BRIDG	DATAOUT	5	B	1783 DLC	SO30	B 9
NR13/A	AB	A	1683 BRIDG	DATAOUT	29	B	1783 DLC	SO30	G10
NR14/A	AB	A	1683 BRIDG	DATAOUT	28	B	1783 DLC	SO30	E10
NR15/A	AB	A	1683 BRIDG	DATAOUT	4	B	1783 DLC	SO30	C10
NR16/A	AB	A	1683 BRIDG	DATAOUT	3	B	1783 DLC	SO30	A10
NVREF/A	AB	A	1683 BRIDG	DATAOUT	25	B	1783 DLC	SO30	C12
START/B	AB	B	1783 DLC	SO30	B13	A	1683 BRIDG	DATAOUT	49

INSTRUMENT CONNECTIONS

2990-9390 AUTOMATIC IMPEDANCE MEASURING SYSTEM ISSUE NO.1 5-4-73

A 1683 BRIDG 1683-9742 AUTOMATIC CAPACITANCE BRIDGE

SOCKET	PIN	SIGNAL NAME	TO INSTRUMENT		SOCKET	PIN	CABLE
DATAOUT	49	START/B	B	1783 DLC	SO30	B13	AB
DATAOUT	25	NVREF/A	B	1783 DLC	SO30	C12	AB
DATAOUT	3	NR16/A	B	1783 DLC	SO30	A10	AB
DATAOUT	4	NR15/A	B	1783 DLC	SO30	C10	AB
DATAOUT	26	NRNG4/A	B	1783 DLC	SO30	F11	AB
DATAOUT	2	NRNG2/A	B	1783 DLC	SO30	D11	AB
DATAOUT	27	NRNG8/A	B	1783 DLC	SO30	H11	AB
DATAOUT	1	NRNG1/A	B	1783 DLC	SO30	B11	AB
DATAOUT	30	NR10/A	B	1783 DLC	SO30	F 9	AB
DATAOUT	31	NR 9/A	B	1783 DLC	SO30	H 9	AB
DATAOUT	6	NR11/A	B	1783 DLC	SO30	D 9	AB
DATAOUT	7	NR 8/A	B	1783 DLC	SO30	A 8	AB
DATAOUT	5	NR12/A	B	1783 DLC	SO30	B 9	AB
DATAOUT	8	NR 7/A	B	1783 DLC	SO30	C 8	AB
DATAOUT	29	NR13/A	B	1783 DLC	SO30	G10	AB
DATAOUT	32	NR 6/A	B	1783 DLC	SO30	E 8	AB
DATAOUT	28	NR14/A	B	1783 DLC	SO30	E10	AB
DATAOUT	13	NI16/A	B	1783 DLC	SO30	B 5	AB
DATAOUT	14	NI15/A	B	1783 DLC	SO30	D 5	AB
DATAOUT	11	NR 0/A	B	1783 DLC	SO30	A 6	AB
DATAOUT	38	NI14/A	B	1783 DLC	SO30	F 5	AB
DATAOUT	35	NR 1/A	B	1783 DLC	SO30	H 7	AB
DATAOUT	39	NI13/A	B	1783 DLC	SO30	H 5	AB
DATAOUT	34	NR 2/A	B	1783 DLC	SO30	F 7	AB
DATAOUT	15	NI12/A	B	1783 DLC	SO30	A 4	AB
DATAOUT	10	NR 3/A	B	1783 DLC	SO30	D 7	AB
DATAOUT	16	NI11/A	B	1783 DLC	SO30	C 4	AB
DATAOUT	9	NR 4/A	B	1783 DLC	SO30	B 7	AB
DATAOUT	40	NI10/A	B	1783 DLC	SO30	E 4	AB
DATAOUT	33	NR 5/A	B	1783 DLC	SO30	G 8	AB
DATAOUT	20	NI 3/A	B	1783 DLC	SO30	C 2	AB
DATAOUT	44	NI 2/A	B	1783 DLC	SO30	E 2	AB
DATAOUT	19	NI 4/A	B	1783 DLC	SO30	A 2	AB
DATAOUT	45	NI 1/A	B	1783 DLC	SO30	G 2	AB
DATAOUT	43	NI 5/A	B	1783 DLC	SO30	H 3	AB
DATAOUT	21	NI 0/A	B	1783 DLC	SO30	B 1	AB
DATAOUT	42	NI 6/A	B	1783 DLC	SO30	F 3	AB
DATAOUT	23	INHIBIT/B	B	1783 DLC	SO30	G12	AB
DATAOUT	18	NI 7/A	B	1783 DLC	SO30	D 3	AB
DATAOUT	50	GNDCH/A	B	1783 DLC	SO30	H13	AB
DATAOUT	17	NI 8/A	B	1783 DLC	SO30	B 3	AB
DATAOUT	37	GND R&D8/A	B	1783 DLC	SO30	G 6	AB
DATAOUT	41	NI 9/A	B	1783 DLC	SO30	G 4	AB
DATAOUT	46	GND L&C4/A	B	1783 DLC	SO30	F 1	AB
DATAOUT	22	GND L&C2/A	B	1783 DLC	SO30	D 1	AB
DATAOUT	47	GND L&C8/A	B	1783 DLC	SO30	H 1	AB
DATAOUT	48	COLOR/A	B	1783 DLC	SO30	E12	AB
DATAOUT	12	GND R&D2/A	B	1783 DLC	SO30	C 6	AB
DATAOUT	24	BUSY/A	B	1783 DLC	SO30	A12	AB
DATAOUT	36	GND R&D4/A	B	1783 DLC	SO30	E 6	AB

INSTRUMENT CONNECTIONS

2990-9390 AUTOMATIC IMPEDANCE MEASURING SYSTEM ISSUE NO.1 5-4-73

1783 DLC 1783-9003 DIGITAL LIMIT COMPARATOR

SOCKET	PIN	SIGNAL NAME	TO INSTRUMENT			SOCKET	PIN	CABLE
S030	E 6	GND R&D4/A	A	1683	BRIDG	DATAOUT	36	AB
S030	C 6	GND R&D2/A	A	1683	BRIDG	DATAOUT	12	AB
S030	G 6	GND R&D8/A	A	1683	BRIDG	DATAOUT	37	AB
S030	H 1	GND L&C8/A	A	1683	BRIDG	DATAOUT	47	AB
S030	H13	GNDCH/A	A	1683	BRIDG	DATAOUT	50	AB
S030	G12	INHIBIT/B	A	1683	BRIDG	DATAOUT	23	AB
S030	F 1	GND L&C4/A	A	1683	BRIDG	DATAOUT	46	AB
S030	D 1	GND L&C2/A	A	1683	BRIDG	DATAOUT	22	AB
S030	B 1	NI 0/A	A	1683	BRIDG	DATAOUT	21	AB
S030	E12	COLOR/A	A	1683	BRIDG	DATAOUT	48	AB
S030	G 2	NI 1/A	A	1683	BRIDG	DATAOUT	45	AB
S030	A12	BUSY/A	A	1683	BRIDG	DATAOUT	24	AB
S030	E 2	NI 2/A	A	1683	BRIDG	DATAOUT	44	AB
S030	G 4	NI 9/A	A	1683	BRIDG	DATAOUT	41	AB
S030	B 3	NI 8/A	A	1683	BRIDG	DATAOUT	17	AB
S030	E 4	NI10/A	A	1683	BRIDG	DATAOUT	40	AB
S030	D 3	NI 7/A	A	1683	BRIDG	DATAOUT	18	AB
S030	C 4	NI11/A	A	1683	BRIDG	DATAOUT	16	AB
S030	F 3	NI 6/A	A	1683	BRIDG	DATAOUT	42	AB
S030	A 4	NI12/A	A	1683	BRIDG	DATAOUT	15	AB
S030	H 3	NI 5/A	A	1683	BRIDG	DATAOUT	43	AB
S030	H 5	NI13/A	A	1683	BRIDG	DATAOUT	39	AB
S030	A 2	NI 4/A	A	1683	BRIDG	DATAOUT	19	AB
S030	F 5	NI14/A	A	1683	BRIDG	DATAOUT	38	AB
S030	C 2	NI 3/A	A	1683	BRIDG	DATAOUT	20	AB
S030	D 5	NI15/A	A	1683	BRIDG	DATAOUT	14	AB
S030	G 8	NR 5/A	A	1683	BRIDG	DATAOUT	33	AB
S030	B 7	NR 4/A	A	1683	BRIDG	DATAOUT	9	AB
S030	E 8	NR 6/A	A	1683	BRIDG	DATAOUT	32	AB
S030	D 7	NR 3/A	A	1683	BRIDG	DATAOUT	10	AB
S030	C 8	NR 7/A	A	1683	BRIDG	DATAOUT	8	AB
S030	F 7	NR 2/A	A	1683	BRIDG	DATAOUT	34	AB
S030	A 8	NR 8/A	A	1683	BRIDG	DATAOUT	7	AB
S030	H 7	NR 1/A	A	1683	BRIDG	DATAOUT	35	AB
S030	H 9	NR 9/A	A	1683	BRIDG	DATAOUT	31	AB
S030	A 6	NR 0/A	A	1683	BRIDG	DATAOUT	11	AB
S030	B11	NRNG1/A	A	1683	BRIDG	DATAOUT	1	AB
S030	B 5	NI16/A	A	1683	BRIDG	DATAOUT	13	AB
S030	D11	NRNG2/A	A	1683	BRIDG	DATAOUT	2	AB
S030	E10	NR14/A	A	1683	BRIDG	DATAOUT	28	AB
S030	G10	NR13/A	A	1683	BRIDG	DATAOUT	29	AB
S030	C10	NR15/A	A	1683	BRIDG	DATAOUT	4	AB
S030	B 9	NR12/A	A	1683	BRIDG	DATAOUT	5	AB
S030	A10	NR16/A	A	1683	BRIDG	DATAOUT	3	AB
S030	D 9	NR11/A	A	1683	BRIDG	DATAOUT	6	AB
S030	C12	NVREF/A	A	1683	BRIDG	DATAOUT	25	AB
S030	B13	START/B	A	1683	BRIDG	DATAOUT	49	AB
S030	F 9	NR10/A	A	1683	BRIDG	DATAOUT	30	AB
S030	H11	NRNG8/A	A	1683	BRIDG	DATAOUT	27	AB
S030	F11	NRNG4/A	A	1683	BRIDG	DATAOUT	26	AB

PARTS LIST

SHEET 1 OF

INSTRUMENT 2990-9390 AUTOMATIC IMPEDANCE MEASURING SYSTEM

	PART DESCRIPTION	REF. INFO.	PART NO.	REQ.	DWG.NO.
1					
2	AUTOMATIC IMPEDANCE MEASURING SYSTEM		2990 9390		
3					
4	Automatic RLC Bridge		1683 9742	1	
5					
6	Test Fixture		1683 9601	1	
7					
8	Digital Limit Comparator		1783 9003	1	
9					
10	Instructions Form 2990-9390			1	
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
40					
41					
42					
43					
44					
45					

NUMBER 2990-9390-PL/1 ISSUE

GENERAL RADIO COMPANY
CONCORD, MASS. U.S.A.

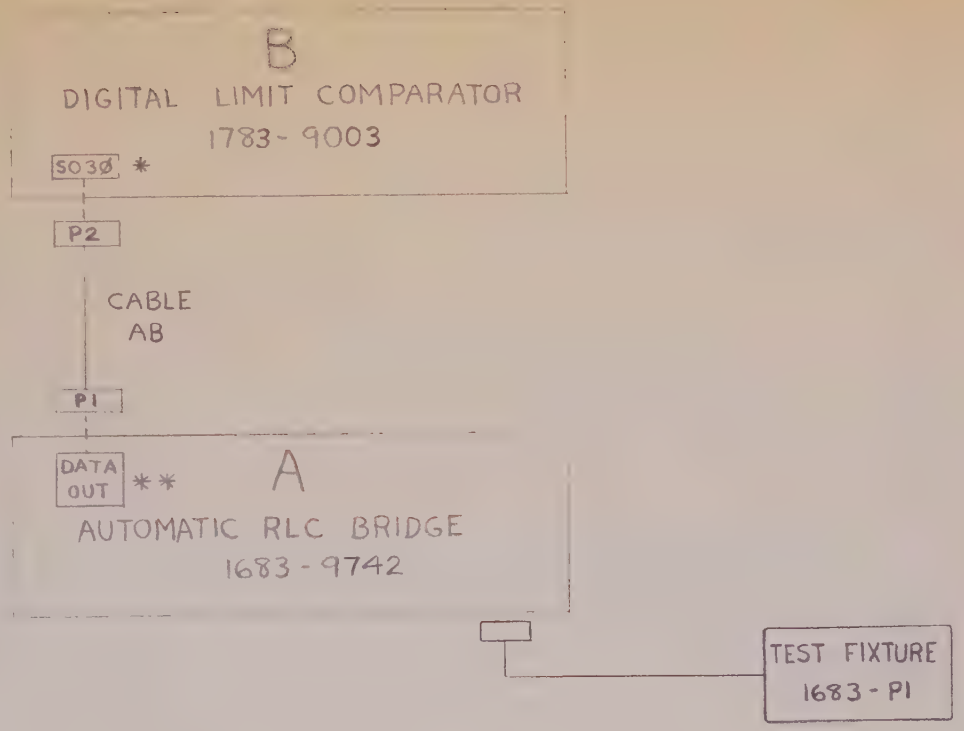
DR. CH. APP. SCALE FIRST USED ON

REVISIONS

FILE DATE 2-21-73 ISSUE 1

NUMBER 2990-9390-PL/1 ISSUE

TECFAX 10-70



2990-9390
AUTOMATIC IMPEDANCE MEASURING SYSTEM
CABLE DIAGRAM

* S03Ø IS BCD DATA INPUT

** DATA OUT IS BOARD "N", S01

CABLE	NUMBER
AB	4205-1200

2990-9390-ID/1

4-6

REVISIONS

KHM — CCF

GENERAL RADIO COMPANY
CONCORD, MASS. U.S.A.

NUMBER 2990-9390-ID/1 ISSUE

Tectax 10-70

PARTS LIST

SHEET 1 OF

INSTRUMENT 1783-9003 DIGITAL LIMIT COMPARATOR

	PART DESCRIPTION	REF. INFO.	PART NO.	REQ.	DWG.NO.
1					
2	DIGITAL LIMIT COMPARATOR		1783 9003		
3					
4	Comparator Asm		1783 3100	1	
5					
6	Instruction Book Form No. 1783-9003			1	
7					
8	Power Cord		4200 9622	1	
9					
10	Data Cable		4205 1200	1	
11					
12	End Frame Set		5310 9624	1	
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
40					
41					
42					
43					
44					
45					

NUMBER 1783-9003PL/1 ISSUE

GENERAL RADIO COMPANY
CONCORD, MASS. U.S.A.

DR. KMP CH. APP. SCALE FIRST USED ON

REVISIONS

FILE DATE 5-1-70 ISSUE 1

NUMBER 1783-9003PL/1 ISSUE

TECPAX 10-70

Theory–Section 4

4.1 GENERAL 4-1
4.2 SIMPLIFIED BLOCK DESCRIPTION 4-3
4.3 BLOCK DIAGRAM DESCRIPTION 4-5
4.4 CIRCUIT DESCRIPTIONS 4-9

4.1 GENERAL.

For simplicity in referencing circuits, the 20 circuit boards and three modules that comprise the instrument are designated by letters. Table 4-1 lists the circuits and their designation. These designation letters are also used to identify schematics and drawings. The first letter of each signal name shown on schematics and diagrams designates the circuit from which the signal originated. The U, F, and G modules contain front-panel indicator lamps and are mounted on the display board (H board).

The bridge measures capacitors, inductors, and resistors. For capacitance measurements, the bridge will give a direct reading of capacitance and at the same time a direct reading of loss expressed as dissipation factor (CsD). As an option, a direct reading of loss expressed as equivalent series resistance (ESR) can be obtained simultaneously by the addition of a "C"-divider board (CsRs).

The bridge also measures inductance and resistance with loss expressed as a series element (LsRs).

The three bridge configurations, (CsD, CsRs and LsRs), which include the Y bridge and K, B, and C (if ESR is included) dividers for these different measurements, are obtained by interconnecting the standards and dividers with the front-panel function switch. The precision dividers then permit a direct reading of the unknown impedance. The addition of a leakage board (L) allows leakage current measurements to be made with capacitance measurements on a "go, no-go" basis, indicated by front-panel indicators.

The instrument, therefore, consists of two major sections, a bridge section and a control section.

The bridge section consists of:

1. Oscillator
2. Power amplifier
3. Y bridge
4. K, B, and C (if installed) dividers
5. Standards mounted on mother (M) board
6. Detector circuit.

The control section consists of:

1. Reference circuit
2. Program circuit
3. Range circuit
4. I1 and 21 (reactance and resistance) counters
5. Control circuit (front-panel).

The instrument also has a data-input circuit for receiving and passing programmed control signals to and from external sources, a data-output circuit for transmitting data to external equipment for recording, a power supply that provides bias voltages and voltages for other functions, and a leakage circuit (optional) for measuring the leakage current of electrolytic-type capacitors.

The control section incorporates several features to produce an extremely fast balance at both 120 Hz and 1 kHz. Among these are:

1. Reversible counters (the 1I and 2I counters) that can count forward as well as reverse.

2. A voltage-controlled oscillator in the reference circuit that causes the counters to count and, therefore, the dividers to switch, at a rate determined by the magnitude of the error (fast for a large error, slower for a small error).

Table 4-1
1683 CIRCUITS

Desig.	Name	Remarks	Paragraph No. Detailed Description
B	B-divider board		4.4.5
C	C-divider board (optional)		4.4.5
D	Detector board		4.4.8
E	Range board		4.4.11
F	Display module	On H board	4.4.15
G	Display module	On H board	4.4.15
H	Display board		4.4.15
1I (I)	Counter board (reactance)		4.4.12
2I (R)	Counter board (resistance)		4.4.12
J	Power amplifier		4.4.3
K	K-divider board		4.4.5
L	Leakage board (optional)		4.4.6
M	Mother board	Serves mainly to connect other boards	4.4.7
N	Data-output board	For recording data	4.4.14
P	Program board		4.4.10
Q	Auxiliary (Data-input) board	For programming the bridge	4.4.13
R	Auxiliary comparator board	On bottom of mother Board	4.4.9
S	Reference board		4.4.9
T	Oscillator board		4.4.2
U	Display module	On H board	4.4.15
V	Power supply		4.4.16
Y	Y-bridge board		4.4.4
Z	Control board	Front panel	4.4.17

3. An anticipator, located on the detector board (D board), which is sort of a floating null that takes into account the error-signal time delay as it propogates through the circuitry, causing the bridge to converge more rapidly than by conventional methods.

General operation is as follows: The unknown is connected and produces an error signal that is amplified and filtered in the detector preamplifier (D board). This error signal is compared to a predicting voltage level (D board) and phase sampled (P board) for direction information, i.e., whether the divider is reading high or low. This will tell the servo (see Figure 4-1) the direction the counters should operate. The error signal is also converted to dc and produces a clock signal (S board), whose frequency is related to the magnitude of the error signal.

The counters are then operating and adjusting the precision dividers in such a way as to minimize the error signal. They will continue to count until either a balance is reached or there is overshoot, at which point the counters will reverse direction and count until balance is finally reached. The anticipator will minimize overshoot and produce the fastest convergence. This system will produce a balance in about 100 periods of the bridge signal frequency for a full-scale (10000 counts) error.

The four-terminal connection to the unknown to be measured enables low impedances to be accurately measured by minimizing the effects of lead impedances. High impedances can also be measured very accurately because stray capacitance is either connected across the oscillator or the low impedance divider (Y divider) and, therefore, is guarded by the low impedance to ground.

4.2 SIMPLIFIED BLOCK DESCRIPTION.

4.2.1 General.

Figure 4-1 shows a simplified block diagram of the 1683. As shown, the system represents a servomechanism in which the error signal is minimized by adjusting the gain of the precision dividers.

The 1683 measures the in-phase voltage across the unknown to obtain a value for its real or resistive component and measures the 90° out-of-phase (quadrature) voltage to obtain a value for its imaginary or reactive component. Since the 1683 is a true bridge, it does not measure these voltages directly but instead creates equal but opposite voltages (correction voltages) that are controlled in such a manner to cancel the unbalance, or error, voltages caused by the unknown. It then presents these voltages (the correction voltage), calibrated in terms of resistance or dissipation factor and capacitance or inductance, to front-panel numerical readout indicators.

4.2.2 Measurement and Bridge Network.

A 120-Hz or 1-kHz measurement voltage, E_T, is applied across a series network comprised of the unknown, R_x and X_x, and a standard resistor, R_s, which results in a current, I_T. A voltage drop, E_{XR}, is produced across R_x, and it is in phase (real) with I_T and a voltage drop, E_{XI}, across X_x that is 90° out of phase (imaginary) with I_T. These two voltages, applied to an isolation amplifier, Y, emerge as voltages E_{YR} and E_{YI}, and are then applied to a standard conductance, G_T. The resultant currents through G_T are the real and imaginary unbalance currents, I_{YR} and I_{YI}, due to the unknown.

The current I_{SR}, through R_s is equal to I_T and in phase with the voltage across R_s. The current, I_{SR}, is converted to a proportional voltage, E_{YR}, which is inverted with respect to I_{SR}. This voltage is applied to two variable-gain amplifiers (B and K dividers). These amplifiers are adjusted by the output of the 1I and 2I counters, which indicate the amount of correction required to reduce an error signal to zero. The output of B is applied to standard conductance G_B, and the K output is applied to standard capacitor C_S. The resultant currents through G_B and C_S are the real and imaginary currents, I_{BR} and I_{KI}, which are inverted with respect to their unbalance-current counterpart.

The unbalance current and the correction currents are summed algebraically and the difference is applied as the error signal to the phase detector (D). The phase detector samples the error signal every 90°. The resultant sampled signal is fed to the reference board (S), which produces a clock signal with a rate related to the magnitude of the error, and to the detector board, which produces the signals that command the counters to count forward or reverse, according to the phase of the sampled signal. For this discussion, the instrument will be considered to consist of two servomechanism loops, the B and the A loops, with the B loops consisting of samples taken at 90° and the A loop at 180°.

4.2.3 Control Section.

B Servo Loop. Assume at the start of a measurement that the gain of the variable-gain-amplifiers is zero, so that both correction currents, I_{BR} and I_{KI} are zero. At the first 90° sample only the real unbalance current, I_{YR}, is seen. (Imaginary unbalance current I_{YI} is zero at 90°.) Assume this current is six units and, as shown, is negative. The 90° sample E_{DR} is applied to a direction-control circuit (P board) that produces a gain-control signal E_{PR}, for the B amplifier. When E_{DR} is negative, E_{PR} is a logic level that directs the 2I counter and, hence, the B amplifier to count forward (F). By the second sample, the B amplifier has increased its gain so that I_{BR} is +2 units and the resultant error, E_{DR}, is $I_{YR} + I_{BR} = -6 + 2 = -4$. The counter then reads 200 units. Since E_{DR} is still negative, E_{PR} is still "F", and the counter and amplifier B continue to count forward.

For the third sample $I_{YR} + I_{BR} = -6 + 4 = -2$. E_{DR} is still negative, E_{PR} forward (F), and amplifier B continues to count forward.

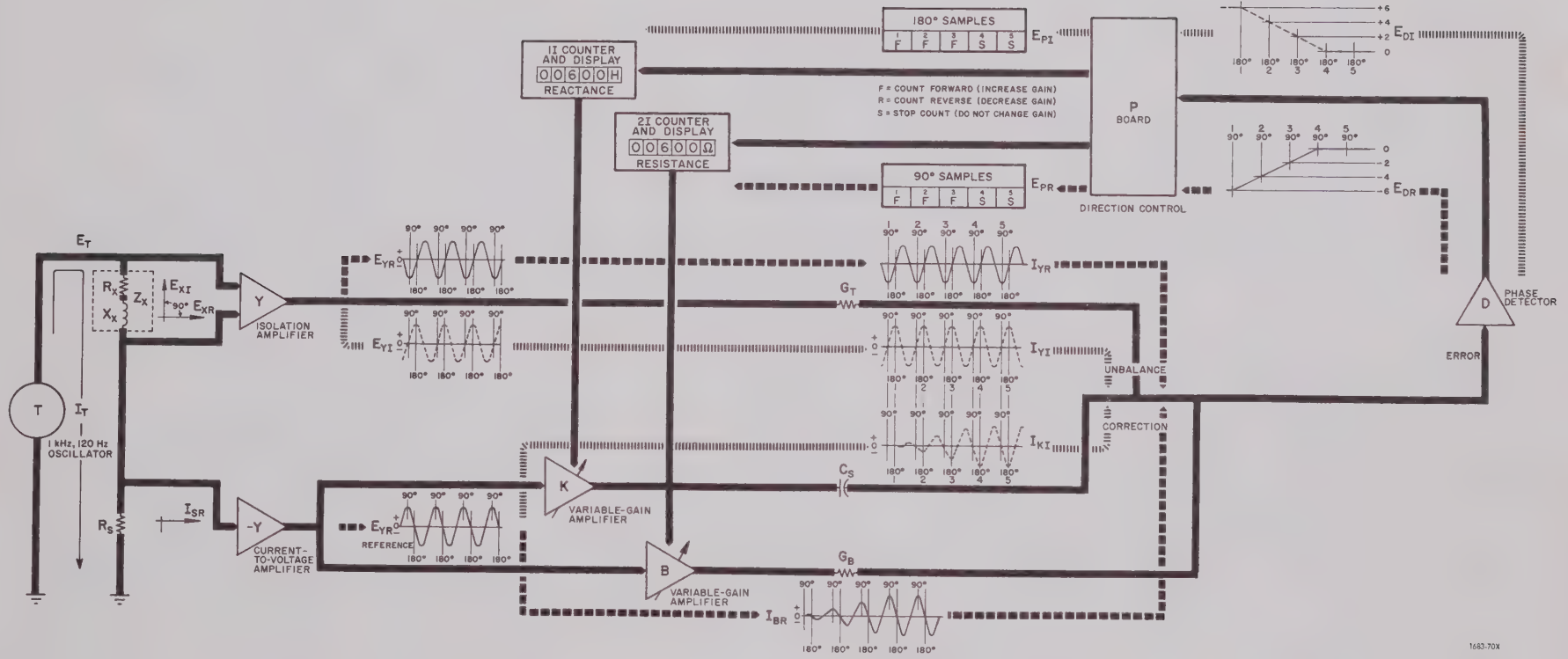


Figure 4-1. 1683 simplified block diagram.

At the fourth sample $I_{YR} + I_{BR} = -6 + 6 = 0$. E_{DR} is now zero, which causes E_{PR} to change from F to stop (S) and holds the gain of amplifier B constant; the real components are balanced. The 2I display has kept track of the gain of the B amplifier and now registers the gain, expressed in terms of resistance, as a measure of the resistive component of the unknown.

A Servo Loop. The A servo loop operates in the same manner as the B, except the samples are taken at 180°, and the significance of the error-signal polarity is the opposite. At the first sample, $I_{YI} + I_{KI} = +6 + 0 = +6$. E_{DI} is positive (opposite to that of E_{DR} of the 90° sample in the B servo loop), which causes I_{PI} to be F and direct amplifier K to count forward.

For sample two, $I_{YI} + I_{KI} = +6 - 2 = +4$. E_{DI} is still positive, E_{PI} is still F, and amplifier K continues to count forward.

At sample four, $I_{YI} + I_{KI} = +6 - 6 = 0$. E_{DI} is now zero, causing E_{PI} to change from F to S, holding the amplifier gain constant; the imaginary components are balanced.

The 1I counter and display has kept track of the gain of amplifier K, registering the gain, expressed in terms of inductance, or capacitance, as a measure of the reactive component for the unknown.

In both loops, if the gain increase overshot the error signal, a E_{PI} or E_{PR} reverse (R) logic signal would be produced, causing the counters to reverse and the amplifier gain to decrease.

4.3 BLOCK DIAGRAM DESCRIPTION.

4.3.1 General.

Figure 6-3 shows a detailed block diagram of the 1683. Also refer to Figure 6-4.

4.3.2 Oscillator.

The oscillator is a Wien-Bridge oscillator that operates at two frequencies, 120 Hz and 1 kHz, selected with the front-panel function switch. The oscillator has two parts, a frequency-determining network and a voltage divider. The voltage-divider network supplies negative feedback to stabilize signal amplitude. The front-panel OSC LEVEL control can vary the oscillator output from 0.2 to 2.2 V, open circuit.

The oscillator signal is gated off for 5 ms during a change of range, gated off during a leakage-current measurement (if made), and gated off when a programmed QOSCOFF signal from an external source is applied to the AUXILIARY socket. The oscillator output is applied to the power amplifier.

4.3.3 Power Amplifier.

The power amplifier increases the bridge-oscillator signal and furnishes an internal dc bias to the part under test, so that the part can be measured under bias and/or its leakage current can be measured. The ac gain of the amplifier is −2.2 and it can supply 2A of current with less than 0.5% distortion. The output impedance is 1 Ω. The bias voltage can be adjusted from 0 V to approximately 3 V with the front-panel BIAS control.

The bias voltage is disabled when the bridge is balanced, when disabled by an externally applied QBIAS signal at the AUXILIARY socket, or when inductance is being measured. The amplifier output is fed to the high-current (HC) terminal.

4.3.4 Terminals.

Four terminals preserve the accuracy of the bridge, even with low-impedance unknowns measured remotely. A fifth terminal (GUARD), or ground, provides a similar safeguard with high impedances whose measurement might otherwise be affected by stray capacitance. Since it is a Kelvin-type connection, the high terminals must be connected together and the low terminals connected together for a measurement.

4.3.5 Y Bridge.

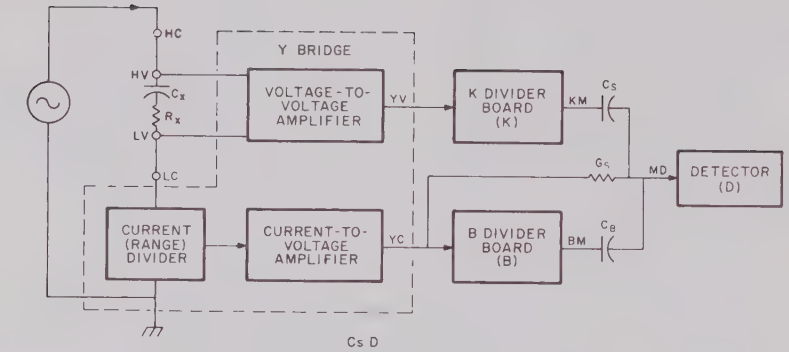
The Y bridge performs three functions: (1) amplifies the voltage across the unknown, (2) converts the current through the unknown to a voltage proportional to the current, and (3) changes the range of the bridge by regulating the current that is converted to a voltage proportional to the current. The voltages produced drive the various standards. The circuit consists of an isolation amplifier and differential amplifier, which act as a voltage-to-voltage amplifier; a current divider (range divider); and R_A amplifier that acts as a current-to-voltage amplifier, converting the current through the unknown to a voltage.

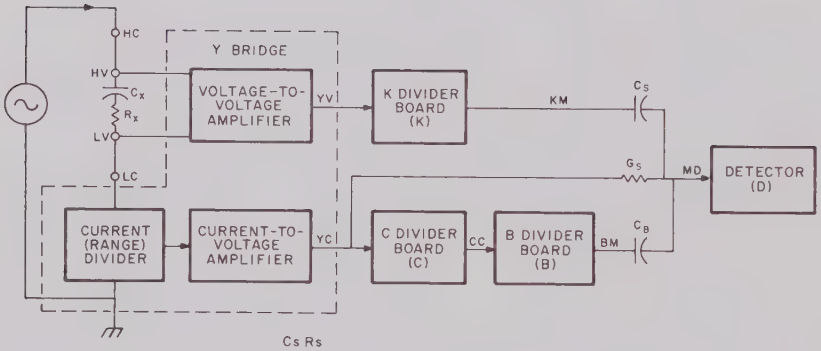
The isolation amplifier produces a high input impedance for the voltage probe (terminal) and has a capacitive -coupled input, so that a polarizing voltage will not affect the circuit bias voltage. The differential amplifier measures the voltage across the unknown, minimizing errors due to lead impedances. The output voltage is proportional to the voltage across the unknown.

The current divider is a resistive divider that, under control of the range selector (either front-panel control, external control or range counter in the range circuit, E board), changes the range of the bridge; it has a range from 1 to 10^9. The R_A amplifier converts the current to a porportional voltage to drive the standards.

4.3.6 Dividers.

The dividers consist of a resistive ladder network (weighted conductances) connected to an output operational amplifier. The K, B, and C (optional) dividers and the standards can be switched by the front-panel mode switch to form three elementary bridge configurations (Figure





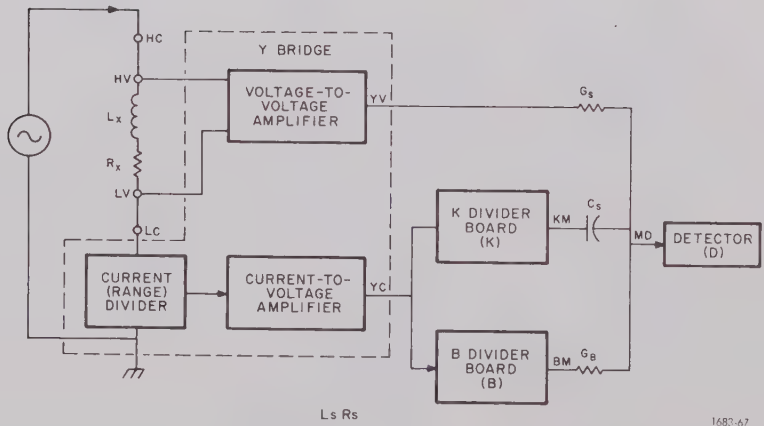


Figure 4-2. Bridge configurations.

4-2) for measuring three functions (CsD, LsRs and Cs with ESR). The optional C divider is for measuring ESR.

The standards used in these bridge configurations are selected so that the values of the dividers give a direct reading of the unknown impedance. The outputs of the reversible counters switch in or out the resistive dividers (weighted conductances) in the ladder network, reducing the error signals to zero and thereby producing a balance. The counters store the amount of attenuation or non-attenuation required to do this and drive the displays that give a readout of the value of the part under test. The three boards are similar, except switch drivers for switching in weighted conductances on the C board are on the K board, and the B board has two configurations of the output operational amplifier, one for dissipation factor measurements and one for ESR measurements (if made). This is because there is a 180° phase shift for ESR measurements and no phase shift for dissipation-factor measurements.

Input relays, under control of the function selector (front-panel function switch or external control), switch in the applicable path for the function being measured. Applicable components for different frequency measurements are also switched in or out by the function selector.

The bridge configurations are controlled by externally applied program signals through the AUXILIARY socket or by the front-panel function switch.

Signal KV, the input signal to the K divider, is also fed to the reference circuit, where it is used as the bridge reference signal for obtaining 0°, 90°, 180°, and 270°, phase signals that are phase-referenced to the error signal. The resultant signals drive the phase detectors (P board).

4.3.7 Leakage-Current Circuit.

This circuit is available as an option. If included, the circuit is activated before a balance operation, if leakage current is being measured, and measures the leakage current on a "go, no-go" basis. The circuit converts the leakage current to a proportional voltage and compares the voltage to a reference voltage selected either by the front-panel LEAKAGE switch or supplied from an external source through the AUXILIARY connector. If the leakage current does not exceed the selected limit within the time (0-10 s) established by the front-panel VARIABLE MEAS. RATE control, indicating the leakage is equal to or less than the limit, the NO GO indicator will extinguish and the GO indicator will light. The NO GO indicator will remain on if the leakage is more than the established limit for the time selected.

4.3.8 Mother Board.

This circuit board contains the standards. The applicable standards are selected by the function selector. The board serves primarily as an intraconnecting assembly.

4.3.9 Detector Circuit.

This circuit consists of four major sections:

1. Preamplifier
2. Anticipator
3. Comparator
4. Peak detector.

The preamplifier section converts the error current to a voltage, amplifies the voltage, filters the signal, and applies the signal to a comparator. The error signal is applied to a peak detector that produces an output level proportional to the error voltage. The resultant level, DEEE, is fed to the S board where it is used to indicate if an error is less than 500 counts or 100 counts and thereby control accordingly (slow down) the rate of the reference clock, SVCO.

The filter output is added to the anticipator function. This signal is amplified and squared; that is, logic levels are produced when the added signal is greater or less than 0 V. This signal (DO) is fed to the P board where it is phase sampled by the flip-flops that produce count-forward or count-reverse signals. Signal DE, the filter output, is also fed to the reference circuit to produce signals that indicate if the bridge's error count is greater than 8 counts and when the error is one count or less.

The anticipator is a floating null that works to minimize time delays and it is driven by the anticipator driver on the P board. The driver is in turn driven by the direction control flip-flops and a START signal, either the one produced by the front-panel START pushbutton switch, an external source, or that produced automatically on the P board at the start of an automatic operation. The anticipator causes the bridge to balance more rapidly than conventional methods allow. This is done by producing a signal that compensates for the signal delay encountered by the error signal passing through the preamplifier and filter. The signal produced by the anticipator simulates the point at which a zero crossing of the error signal would occur had there been no signal delay produced by the preamplifier.

Signals PAB and PAR cause the signal function to rise at the beginning of a balance, decrease as the error decreases, and "hold" while the counting occurs. A reset condition will cause the anticipator function to delay before the start of a measurement. The signal will then rise after the start pulse occurs. The anticipator signal then is fed to the comparator for comparison with the error signal. Squared outputs (signal DO) are produced at the phase-reference points for certain conditions described in paragraph 4.4.10. Signal DO determines whether the direction-control flip-flops should produce forward-, reverse-, or stop-count signals. A stop-count signal will be produced when the anticipator function exceeds the output of the filter.

4.3.10 Reference Circuit.

This circuit has the following functions:

1. Provides 0°, 90°, 180°, and 270°, phase-reference signals to the direction control flip-flop circuit on the P

board for determining which way the counters should count (forward, reverse, or stop).

2. Provides a signal (SUNBAL), via the control board (Z) to the front-panel UNBALANCE indicator, that will light the UNBALANCED indicator while the bridge is in the unbalanced state. (The indicator lights when the error is greater than eight counts.)

3. Determines from a bridge reference signal, KV, taken from the input to the K divider, the magnitude of the reference signal. The error signal is compared to this reference to determine the number of counts of error.

4. Provides a bridge clock (SVCO) that drives the counters (and hence the dividers) at a rate determined by the magnitude of the bridge error (faster for a larger error). There are four clock rates.

Signal DEEE from the detector circuit is fed to a detector that produces the error-less-than-500-counts and error-less-than-100 counts signal. These signals cause the first two changes of the clock rate. Signal DE is used to indicate if an error is less than 8 counts (SUNBAL) and if it is one count or less (SBAL).

Signal SBAL is fed to the range circuit to produce a signal (EBAL) that verifies a balance has occured. This signal is in turn fed to the program circuit to produce a new start pulse for another balance operation (if in the variable measurement rate or remote-automatic modes). This also inhibits the main gates and, therefore, signals EICLK and ERCLK on the range board until the new balance operation begins.

The error sensitivity of the instrument is established by the front-panel SENSITIVITY control, which adjusts the trigger level of the balance comparator.

4.3.11 Program Circuit.

This circuit contains a clock-pulse circuit that produces signal PCLK23 from the bridge clock signal SVCO. PCLK23 is gated through the range circuit main gates to drive the counters and dividers at a rate determined by SVCO. The circuit also has a test generator called the variable measurement rate (VMR) generator. In the variable measurement rate or remote modes of operation, this generator produces "start balance" pulses at a rate determined by the setting of the VARIABLE MEAS. RATE control. The start pulse is produced after a balance is achieved, or after a leakage measurement is made (if desired), to start another balance operation.

In any test mode of operation the generator signal replaces signal SVCO and drives the counters and dividers. In the track mode the generator runs continually, but is not used. The main gates in the range circuit are held open though, so that the clock will drive the counters and dividers continually, even if a balance is achieved. This is useful for stability or drift measurements of a component.

The circuit contains a start-stop circuit. This circuit is comprised of a number of subcircuits:

1. Balance flip-flop and "no-balance" delay
2. Anti-bounce switch
3. Start Circuit.

These circuits produce a start pulse from either the PVMR generator under the conditions described above, the front-panel START pushbutton switch, an externally applied start signal, or a closure to ground introduced externally at the EXT START connector. The circuit also produces signal PRIG that holds the main-gate circuits on the range board open, during the test and track modes of operation or during an unbalanced condition, allowing the clock to drive the counters. This circuit also produces start-leakage-measurement signals ($\overline{\text{PSTL}}$, $\overline{\text{PLEAK}}$, and $\overline{\text{PLEAKOFF}}$) that start a leakage measurement during the leakage mode of operation.

The program board also contains the direction-control circuit. This circuit consists of a number of phase-detector flip-flops that store direction information. The reference signals from the reference board and the bridge error signal, DO, are applied together to the flip-flops, which are clock-type flip-flops. The flip-flops change state according to the relationship of error signal DO to the phase reference signals. The signals produced are forward, reverse, and stop the 1I and/or 2I (R) clocks. The logic levels of signals PIR and PRR determine these conditions. These signals are also fed to an anticipator-generator driver in the circuit that produces signals PAR and PAB that command the anticipator generator in the detector circuit to produce a rising signal for the start of a balance, a decaying signal for a decreasing error, and a "hold" signal while the counters count and adjust the dividers. Lamps are provided on the board to check the operation of the direction-control flip-flops.

4.3.12 Range Circuit.

This circuit has a reversible range counter and a decoder that establishes the range of the 1683 in the automatic or automatic-remote modes of operation by switching in or out the applicable resistance in the current-divider network at the input of the Y-bridge circuit. This counter also drives the decimal-point indicators and unit symbols on the front-panel display (H). This data can also be sent, via the data-out board, to peripheral equipment for recording or other operations.

The circuit also has a range-control circuit that receives inputs from the counters and other functions that indicate that the instrument should change range (automatic mode), and, if so, cause the range counter to range up or down according to the direction determined. If a change of range is required, a signal, $\overline{\text{ECHANGE}}$, is produced by a range-delay circuit to inhibit the main gates and to prevent the program circuit from producing a "balanced" condition, in case a balance condition is present during a change of range. The range-delay circuit also produces a signal that allows the range counter to change the range if a change is

required. This signal is delayed by the circuit to allow circuits to "settle down."

The range circuit also has the main gates that gate the clock pulses to the counters. These gates pass the clock signals to the counters, except during a bridge-balanced condition, leakage-current measurement, or during a change or possible change of range.

The range counter has lamps on the board that indicate in BCD 1-2-4-8 weighting the state of the counter flip-flops. Each gate on the main gate has a lamp that lights when clock pulses are being gated to the counters. The direction-control circuit has two lamps, one that indicates the counter should be counting forward and one that indicates that it should be counting reverse.

4.3.13 Counters.

Both counters are four-stage reversible counters. The 1I (I) counter counts reactance, the 2I (R) counter resistance and dissipation factor. They provide digital outputs in 1-2-4-8 BCD that can be decoded to decimal readouts (0 through 9); drive other circuits; and produce digital levels when a certain number of pulses have been counted, to be used by the range circuit for ranging determination.

The logic level of the PIR and PRR signals determine the direction the counters should count — forward or reverse. The counters count from 00000 up to 19999 and consist of four stages and one tens-of-thousands (Spillover) flip-flop. The spillover flip-flop indicates the four decade counters have exceeded a count of 9999. The outputs of the counters are fed to the display board where they are decoded to drive the appropriate numerals of the numerical readout tubes. The outputs are also fed to the DATA-OUTPUT socket (N), to drive peripheral recording equipment.

Decoded counts of 00000 and a reverse PIR or PRR signal; 00XXX (spill flip-flop and "thousands" decade read 00); and 19999 and a forward PIR or PRR signal are fed to the range circuit, to be used to determine an up-range or down-range change in the automatic-range mode of operation. The counters can be set to zero with the front-panel SET ZERO pushbutton switch.

4.3.14 Control Board.

The front-panel control board controls the operation of the instrument. These controls are described in paragraph 1.3. Most of the program signals that are received from and transmitted to peripheral equipment are routed through the control board when the controls are set to the REMOTE position. Range information from the range counter in the range circuit is applied to a matrix on this board that in turn drives the decimal-point indicators and symbols on the front-panel display board.

4.3.15 Data-Output Board.

This board serves as an interconnection between external recording equipment and the 1683; this circuit board is an optional item. The board supplies external equipment, via its plug receptacle, the outputs of the 1I and 2I counters, and the range counter in the range circuit in a BCD weighting of 1-2-4-8, plus two control signals, PABORT which indicates a failure to balance after 2.5 s and PBUSY that indicates a balance is started and in process.

The board also can receive a "start" signal from external equipment and an INHIBIT signal that can be used to inhibit a balance.

Two types of boards are available, a low-level data and a high-level data board. The low-level board is for standard TTL logic levels (logical "0" ground with a 10-mA sink capability, logical "1" ≥3.5 V). The high-level is the same as the low-level, except all outputs are a 15-V swing (logical "0" ground with a 10-mA sink capability, logical "1" +15 V behind 12 kΩ). The IC modules on each circuit board are interchangeable, however, with provisions made for suitable biasing connections.

4.3.16 Auxiliary Board.

This board serves as an interconnecting device between external equipment and the 1683 for remote programming. Both input and output control signals are routed through the board. All control functions, except line voltage, are available for remote programming. Input gates on the board are enabled when front-panel controls are set to the REMOTE position.

4.3.17 Display Board.

This board contains drivers and decoders that decode the outputs of the counters to drive the numerical readout tubes mounted on the board. Range and function inputs from the control board drive the decimal indicators and symbol lamps. Three modules (F, U, and G) containing the symbol and nomenclature lamps are also mounted on the board.

4.3.18 Power Supply.

The power supply provides 250 V to the numerical readout tubes on the display board. It also supplies regulated voltages of +15, −15, +5, and +10 V for biasing circuits. In addition, the supply furnishes +8 and −8 V to the power amplifier and a synchronizing signal to the oscillator, to prevent any "beating" effect introduced by the line voltage.

4.4 CIRCUIT DESCRIPTIONS.

4.4.1 General.

The following paragraphs contain circuit descriptions of all the 1683 circuits in the signal flow order shown in Figure 6-3. In the following discussion, logical "1" is defined as a 3.5-V-to-5-V level and a logical "0" is approximately ground.

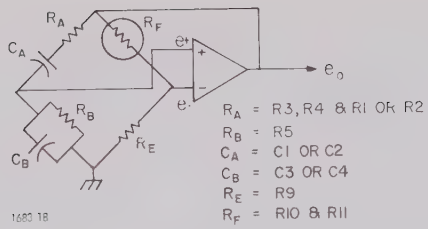


Figure 4-3. Oscillator equivalent.

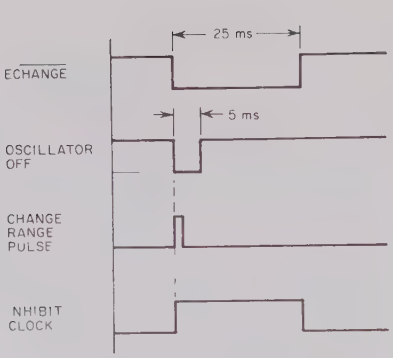


Figure 4-4. Oscillator timing.

4.4.2 Osciliator (Figure 6-23).

Figure 4-3 shows an equivalent circuit of the oscillator (T board). The oscillator is a Wien bridge oscillator that can be considered to consist of two parts, a frequency-determining network (C_A, C_B, R_A and R_B) that supplies positive feedback to sustain oscillation, and a voltage divider (R_F and R_E) that supplies negative feedback to stabilize the amplitude.

The oscillator has two frequencies, 120 Hz and 1 kHz, selected by the function selector (front-panel or external control). The frequencies are selected by changing the values of C_A and C_B by switching in reed switches K3 and K4 with transistors Q3 and Q4. R_F is a thermistor that adjusts itself to the value needed to maintain a constant amplitude oscillation.

The net gain of the bridge amplifier loop is (1/3) 3, or +1, and the circuit oscillates at frequency f_o.

R_A, because of $R3$, has a positive temperature coefficient that cancels the negative temperature coefficient of the capacitors, limiting frequency drift due to temperature. Distortion is less than 0.5% at both frequencies. Signal ZS3 is a "0" when the function selector is set to any 120-Hz position, and a "1" when set to any 1-kHz position. A "0" switches in C8 and C9. At 120-Hz, Q3 and Q4 are turned on and ASYNC from terminal 20 of line transformer T1 synchronizes the oscillator with the line frequency, to eliminate any beating effect.

Q5 and Q7 function as a switch to gate off the oscillator when the bridge is either changing range, as denoted by signal $\overline{\text{ECHANGE}}$ (duration of 25 ms or less), which is a "0" during a change of range; when leakage is being measured, denoted by a "1" $\overline{\text{PLEAKOFF}}$ signal from flip-flop IC28 on the P board; or when the oscillator is programmed "off" by signal QOSCOFF. A "0" at IC2(8) turns on Q7, which turns on Q5 to provide the oscillator signal to the power amplifier (J board) and then to the part under test. The timing circuit (R24, C7) reduces the 25-ms or less $\overline{\text{ECHANGE}}$ pulse to 5 ms, therefore inhibiting the oscillator during the first 5 ms of a range or possible range change. This allows the oscillator signal to propagate through the circuits after the range has been changed but before the range-change inhibit is removed. Figure 4-4 illustrates the range-change timing and oscillator timing sequence.

R20 is a gain adjustment. The oscillator signal, TOSC, is fed to a potentiometer (A-R1) on the front panel where it can be varied from 0.25 to 2.2 V by the OSC LEVEL control for application to the power amplifier (J board).

4.4.3 Power Amplifier (Figure 6-13).

The power amplifier (J board) amplifies the bridge-oscillator signal and provides an internal dc bias to the part under test, so that the part can be measured under bias and/or its leakage current can be measured.

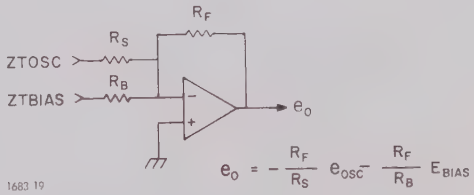


Figure 4-5. Power amplifier equivalent circuit.

Figure 4-5 shows the equivalent circuit of the amplifier.

The input to the amplifier is a 1-V, rms, 120-Hz or 1-kHz signal from the bridge oscillator (T board). The gain of the amplifier is −2.2, and it can supply two amperes of current with <0.5% distortion. The circuit is short-circuit proof.

The gain for bias is also −2.2, and a negative voltage (ZTBIAS) is supplied through a potentiometer, A-R2, on the front panel. This voltage can be adjusted from 0 V to approximately 3 V with the front-panel BIAS control. The signal can then ride on an internal bias of up to 3 V to ensure polarization of capacitors. R5 sets the amplifier output level to 0 V with no ZTBIAS. R27 is a stray capacitance adjustment and is available at the rear panel (A-R27). The output of this adjustment, JTOSC, is fed to capacitor C17 on the mother board (M board). The

capacitor is connected to the low-voltage terminal (LV) of the Y bridge, via the mother board. This adjustment allows the cancellation of stray capacitance across the test terminals.

The PBUSY signal from the P circuit indicates that the bridge is in an unbalanced condition. When the bridge is unbalanced, PBUSY is a logical "1". When the bridge is balanced, PBUSY goes to "0" and disables the bias. $Q\overline{BIAS}$, from an external source, will override PBUSY and enable the internal bias, when $Q\overline{BIAS}$ is a logical "0".

ZS2, a logical "1", indicates an inductance measurement is being made. When this occurs, the signal disables the bias input.

External bias of up to 600 V can be applied in series with the J board JHC terminal and the part under measurement by applying a bias voltage to the BIAS connection on the rear panel.

4.4.4 Y Bridge (Figure 6-26).

General. The Y bridge performs three functions: (1) detects the voltage across the unknown, (2) converts the current through the unknown to a voltage proportional to the current, and (3) changes the range of the bridge by regulating the current that is converted to a voltage proportional to the current. The voltages produced by the Y bridge drive the various standards. Figure 4-2 shows the various configurations in which the Y bridge is used for measuring impedance.

Figure 4-6 shows a simplified block diagram of the Y bridge.

As shown, the circuit consists of an isolation amplifier and differential amplifier, which act as a voltage-to-voltage amplifier; a current divider (range divider); and R_A amplifier that acts as a current-to-voltage amplifier.

The isolation amplifier produces a high input impedance for the voltage probe and has a capacitive-coupled input, so that a polarizing voltage will not affect the circuit bias voltage. The differential amplifier is a high-gain feedback amplifier that measures the voltage across the unknown, minimizing errors due to lead impedances. Output voltage YV is proportional to voltage E_x, the potential across the part under test.

The current divider (range divider) is a resistive divider that, under control of the RANGE selector (front panel or external control), determines the range of the bridge. The divider has a range from 1 to 10^6, and the current output of the divider is determined by

$$i_{out} = \frac{i_{in}}{N}$$

where

$$N = 1 \text{ to } 10^6$$

Table 3-1 lists the range limits and accuracy.

Voltage-to-Voltage Amplifier. The voltage-to-voltage amplifier consists of the isolation amplifier (Q1-Q4) and the differential amplifier (Q5-Q9). As mentioned previously, the isolation amplifier serves as a buffer for the high voltage (HV) probe. The amplifier has unity gain. Q31 serves as a switch to quickly discharge C1, following the application of a bias voltage. Figure 4-7 shows a simplified schematic of the amplifier.

The voltage at point B is one-half that at point A. When the input voltage increases rapidly due to a sudden application of bias, Q35, Q36 and Q31 are turned on, causing C1 to discharge quickly to ground through Q31.

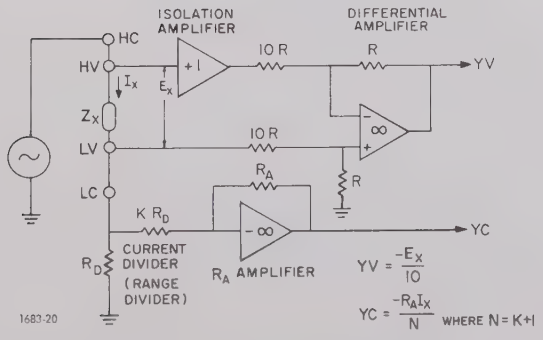


Figure 4-6. Y-bridge block diagram.

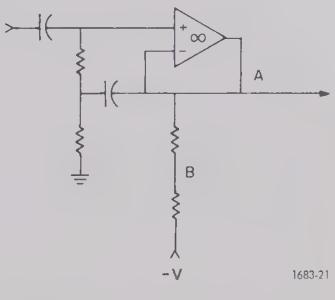


Figure 4-7. Simplified schematic of amplifier.

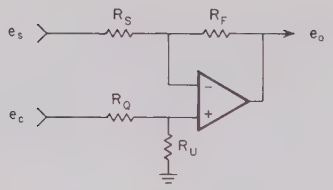


Figure 4-8. Differential amplifier.

The differential amplifier is a standard type amplifier. Figure 4-8 shows the amplifier.

If

$$\frac{R_U}{R_Q} = \frac{R_F}{R_S}$$

then, the output is defined by

$$e_o = \frac{-R_F}{R_s} (e_s - e_c)$$

Therefore, the output of the amplifier is proportional to the differential voltage present at the input.

The relays switch in the appropriate resistor for each range resistance. Table 4-2 is a truth table listing the logic signals, range, and relays operated by each signal. Note in the schematic $\overline{\text{PLEAKOFF}}$ from the P board de-energizes the relays, so that no current will flow through the range divider during leakage measurements.

Q10 listed in Table 4-2 is considered to be a switch. A 1 indicates a turned-on transistor, a 0 a turned-off transistor.

Range Divider. The range divider consists of Q10 and Q21-Q30; relays K1-K6; IC1-IC3 and other associated circuitry. $\overline{\text{ZRNG1}}$-$\overline{\text{ZRNG9}}$ are outputs of the range counter on the E board, routed through the Z board. These signals can also be received from external equipment when the instrument is in the remote mode of operation. CR26 and CR27 provide protection for the circuit if a charged capacitor is connected to the instrument.

Current-to-Voltage Amplifier. The current-to-voltage R_A amplifier converts the current into a voltage to drive the standards. The amplifier is a basic operational type. The transfer impedance is R_A. If the amplifier becomes saturated, a "0" $\overline{\text{YDOWN}}$ signal is produced by Q33 and Q37. This signal is fed to the range board. If the bridge is in the automatic-range mode, the signal will cause the circuit to produce a down-range command to the range counter that

Table 4-2
RELAY TRUTH TABLE

Range	Signal	Relays 1	2	3	4	5	6	7	8	9	10	11	12
0	—	0	0	0	0	0	0	0	0	0	0	0	0
1	$\overline{\text{ZRNG1}}$	1	0	0	0	0	0	0	0	1	1	1	1
2	$\overline{\text{ZRNG2}}$	0	1	0	0	0	0	0	0	1	1	1	1
3	$\overline{\text{ZRNG3}}$	0	0	1	0	0	0	0	0	1	1	1	1
4	$\overline{\text{ZRNG4}}$	0	0	0	1	0	0	0	0	1	1	1	1
5	$\overline{\text{ZRNG5}}$	0	0	0	0	1	0	0	0	1	1	1	1
6	$\overline{\text{ZRNG6}}$	0	0	0	0	0	1	0	0	1	1	1	1
7	$\overline{\text{ZRNG7}}$	0	0	0	0	0	0	1	1	0	0	1	1
8	$\overline{\text{ZRNG8}}$	0	0	0	0	0	0	1	1	0	0	0	1
9	$\overline{\text{ZRNG9}}$	0	0	0	0	0	0	1	1	0	0	0	0

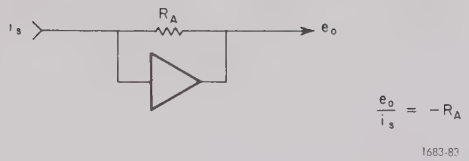


Figure 4-9. R_A amplifier.

controls the current divider. It will also be used to light the front-panel RANGE indicator.

Figure 4-9 shows the R_A amplifier. As indicated, R_A is the transfer impedance of the amplifier.

4.4.5 K, C, and B Dividers (Figures 6-14, 6-5, and 6-6).

General. With the Y-bridge circuit, the K-, C-, and B-divider boards can be switched by the function selector to form three elementary bridge configurations for measuring: (1) C with D as a loss, (2) C with equivalent series resistance (ESR) as a loss, and (3) L_s and R_s. Figures 4-10 through 4-12 show a functional representation of the three configurations. The C divider is an available accessory for ESR measurements.

The formula for C with D as a loss is derived as follows:

At balance (null)

$$i_a + i_b + i_c = 0$$

or

$$-e_a \alpha_S C_S + e_b G_B + e_b \beta_S C_B = 0$$

but

$$e_a = -i_x \left(R_x + \frac{1}{SC_x}\right) \frac{1}{10}$$

and

$$e_b = \frac{-i_x R_A}{N}$$

Substituting and rearranging:

$$C_x = \frac{\alpha N C_S}{10 R_A G_B}$$

$$D_x = \omega \beta R_B C_B$$

For ESR make all β's $\equiv \alpha\beta$

$$C_x = \frac{\alpha N C_S}{10 R_A G_B}$$

$$R_x = \frac{\beta R_A 10}{N} \bullet \frac{C_B}{C_S}$$

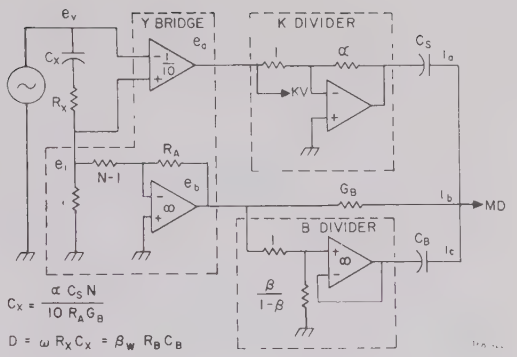


Figure 4-10. Cs with D as a loss bridge configuration.

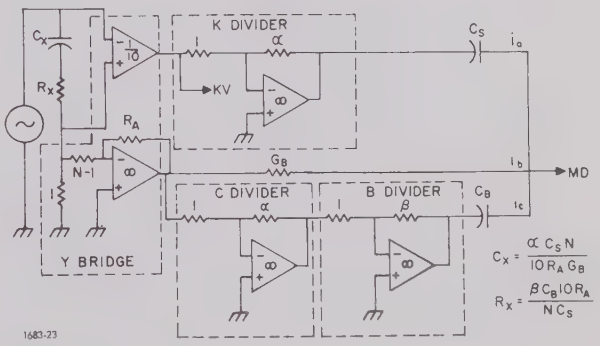


Figure 4-11. Cs with equivalent series resistance bridge configuration.

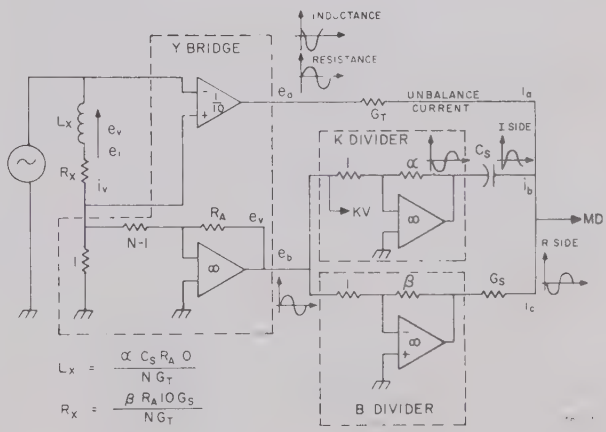


Figure 4-12. Ls with Rs bridge configuration.

The formula for Ls with Rs is derived as follows:

At balance

$$i_a + i_b + i_c = 0$$

or

$$e_a G_T - e_b \alpha_S C_S - e_b \beta G_S = 0$$

but

$$e_a = -i_x \frac{(R_x + SL_x)}{10}$$

$$e_b = \frac{-i_x R_A}{N}$$

Substituting and rearranging:

$$L_x = \frac{\alpha C_S 10 R_A}{N G_T}$$

$$R_x = \frac{\beta R_A 10 G_S}{N G_T}$$

As shown in the figures, the three bridge configurations are obtained by interchanging the standards. The standards (G_T, G_s, C_S, B_G, and C_B) are selected so that the values of the dividers give a direct reading of the unknown impedance. The outputs of reversible counters vary the resistive dividers in the divider circuits that reduce error signals to effect a balance. The counters accumulate the amount of attenuation or non-attenuation required to do this and therefore drive the displays to indicate the value of the part under test. The three divider boards are similar, except switch drivers for the C board are on the K board, and the B board has a provision for two configurations of the operational amplifier. Each divider consists of transistor switches with drivers, a set of weighted conductances (ladder network), and an operational amplifier. The dividers control the voltages applied to the capacitance and conductance standards and are controlled by binary outputs from the reversible counters. (Refer to paragraph 4.4.12).

Ladder Network. Figure 4-13 shows the equivalent divider circuit.

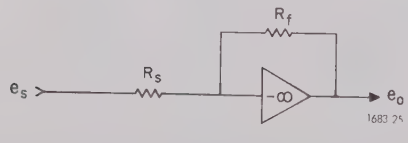


Figure 4-13. Equivalent divider circuit.

Therefore,

$$\frac{e_o}{e_s} = \frac{-R_f}{R_s} = -\alpha$$

where

$$\frac{R_f}{1.9999} \leqslant R_s \leqslant \infty$$

so that

$$0 \leqslant \alpha \leqslant 1.9999$$

R_s is the effective resistance of the ladder network (Figure 4-14), where individual resistors, or conductances, are either connected to ground or the voltage source. Each element of the network is weighted, so that the output is varied in discrete steps from 0 to 1.9999. The divider is comprised of four decades and one spillover (tens-of-thousands) digit. Figure 4-14 shows an equivalent circuit of the ladder network (one decade of the divider). The spillover digit is not shown.

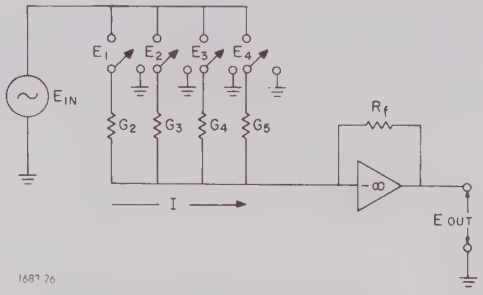


Figure 4-14. Ladder network equivalent circuit.

For the circuit, $E_{out} = -E_{IN} R_f G_w$. Each conductance is weighted in a 1-2-4-2 code. A diode conversion matrix converts the decade counter outputs (1-2-4-8) to 1-2-4-2 for the conductance ladder. In the 1-2-4-2 code, for example:

$G_2 = 0.1$
$G_3 = 0.2$
$G_4 = 0.4$
$G_5 = 0.2$

If $E_{IN} = -1$ V and $R_f = 1$, then any value of voltage E_{OUT} can be obtained in 0.1-V increments by switching in one or more of the four weighted conductances. For example, if G_3 and G_4 are switched in:

$$E_{OUT} = -(-1)\ (1)\ (0.2 + 0.4) = 0.6\ \text{V}$$

Higher voltages and finer increments are obtained by the addition of more weighted conductances. Each divider

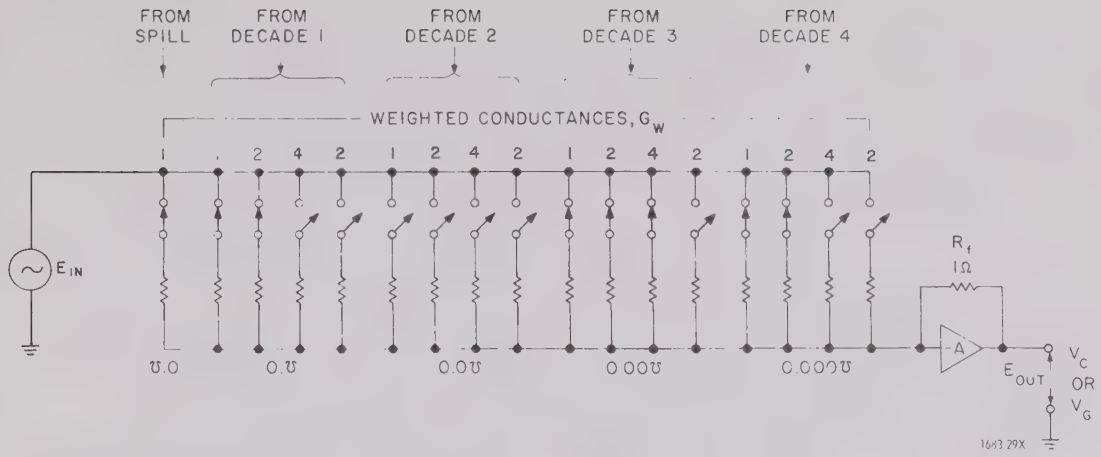


Figure 4-15. Divider.

contains the equivalent of 17 weighted conductances that allow E_{OUT} to be any value from 0 to 1,9999 V. Figure 4-15 shows a representation of the divider.

Figure 4-16 shows an example of what the output would be with the switches closed as shown in the figure. Bear in mind that a matrix (shown in Figure 4-20) is used to convert the code to 1-2-4-8. A closure of the last "2" switch in any decade produces an 8-count code indication.

E_{OUT} = (+1) (1) (1.0 +
0.1+
0.2+
0.00+
0.001 +
0.002 +
0.004 +
0.0001 +
0.0002 =

\+ 1. 3 0 7 3 volts

Figure 4-16. Divider output.

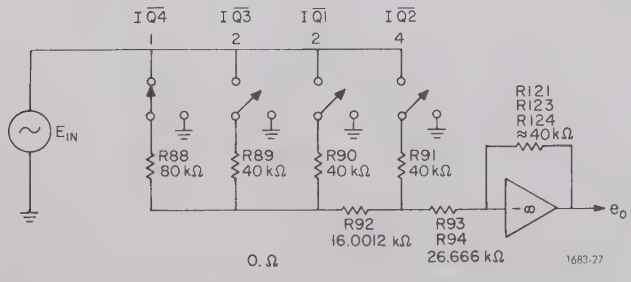


Figure 4-17. Ladder network.

The circuit incorporates a ladder network for each weighted-conductance group. Figure 4-17 shows a ladder network for a typical decade on a divider board.

R_f consists of R121 in series with the parallel combination of R123 and R124, for a total value of 40 kΩ. The equivalent conductances range from 2.5 n℧ for a 100-μV output to 25 μ℧ for a 1-V output.

The output, e_o, is defined by

$$e_o \approx -E_{IN} \left(\overline{IQ4} + 2\,\overline{IQ3} + 2\,\overline{IQ1} + 4\,\overline{IQ2}\right)\left(\frac{40\ k\Omega}{400\ k\Omega}\right)$$

where IQ; = "0" for switch to ground
= "1" for switch to E_{IN}

Amplifier.

Figure 4-18 shows equivalent circuits of the network.

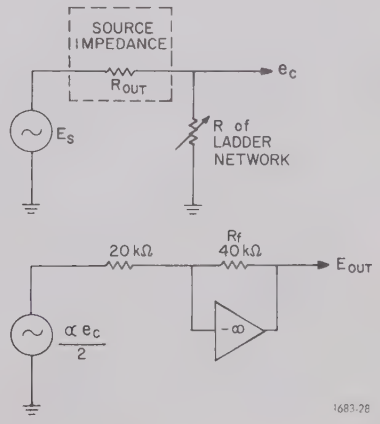


Figure 4-18. Equivalent circuits.

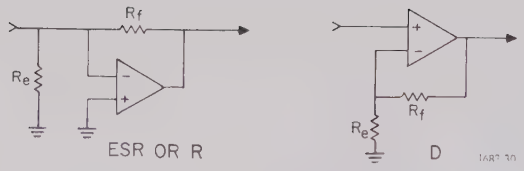


Figure 4-19. Equivalent circuits.

The amplifier always sees 20 kΩ for a source impedance. The amplifiers produce a 180° phase shift of the signal. The B-divider circuit (for C_s measurements) has two amplifier configurations; one for dissipation-factor measurements and one for resistance measurements. The applicable configuration is switched by the front-panel function switch. When measuring dissipation factor, relay K25 is activated, closing a contact and applying the signal to the plus (+) input of the amplifier. Relays K24 and K26 are de-energized, preventing the signal from being applied to the negative (—) input and allowing the positive side to be activated. When resistance is being measured, the opposite happens, the signal being applied to the negative input. Figure 4-19 shows the equivalent circuits for both conditions.

For resistance measurements there is a 180° phase shift; for dissipation factor measurements there is no phase shift.

Input Relays. The relays at the inputs to the divider circuits switch in the applicable path (or divider) for the function being measured. The function selector produces signals ZS1 through ZS4 that control these relays. These signals (ZS1-ZS4) can also be supplied either by the front-panel function switch or the AUXILIARY connector. The external signals are $\overline{LR}$, $\overline{CD}$, and $\overline{CR}$ for function control and $\overline{1000}$ for frequency control. Refer to paragraph 4.4.13 for a further description of these signals.

The C-board amplifier has two feedback resistances, R_f; one of approximately 30 kΩ for 120-Hz operation and one of approximately 25 kΩ for 1-kHz operation. When the function selector is set to 120 Hz, relay K40 is de-energized. Relay contact K40S is opened, and the signal is passed through the parallel combination of R121 and R122 in series with R123, R124 and the parallel combination of R125 and R126. When the selector is set to 1 kHz, the relay is energized, closing the contact and thereby bypassing R121, R122, and R123.

Adjustments. All the operational amplifiers have adjustments for precisely setting the gain. The C board has two adjustments — R121 and R125 — for setting the gain at .01%.

The B-board amplifier has three adjustments; C15, R133, and R124. C15 is a phase adjustment for a zero

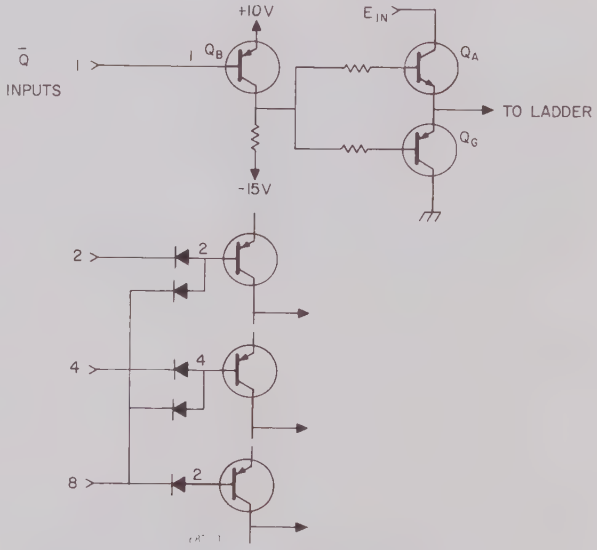


Figure 4-20. Conversion matrix.

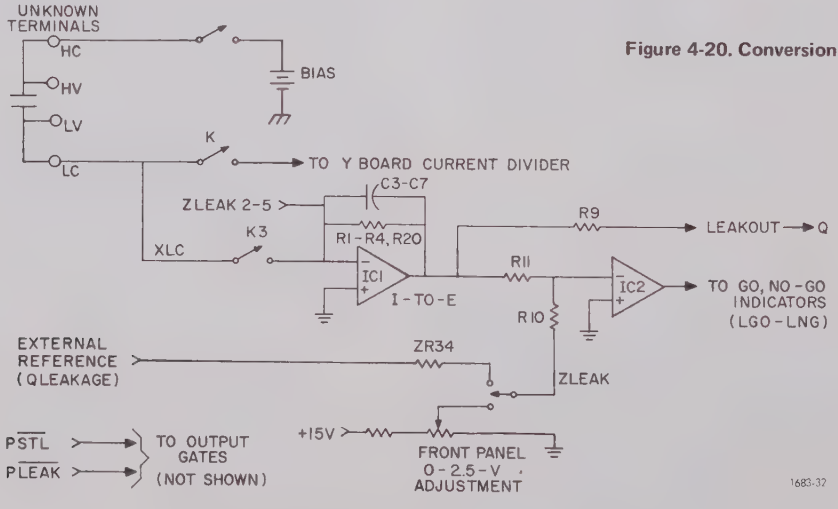


Figure 4-21. Leakage-current circuit block diagram.

Table 4-3
MAGNITUDE OF RANGE AND
FEEDBACK NETWORK FOR EACH LEAKAGE RANGE

Range	Network		Switch
	R_F (Ω)	C_F (μF)	
1 μA (0.1-2.5 μA)	R20, 1 M	C7, .01	Always in network
10 μA (1-25 μA)	R4, 110 k	C6, 0.1	Q6 FET
100 μA (10-250 μA)	R3, 10.1 k	C5, 1.0	Q5 FET
1 mA (0.1-2.5 mA)	R2, 1 k	C4, 10	K2
10 mA (1-25 mA)	R1, 100	C3, 120	K1

phase shift. R133 and R124 are adjustments to set the gain to .01%.

The K board has one adjustment, R124. This adjustment is for setting the accuracy of the gain.

Switch Matrix. The switches that control the weighted conductances, as represented in Figure 4-15, are driven by the $\overline{Q}$ outputs of the counters (1I and 2I). The counter decade weighting is 1-2-4-8, and the divider weighting is 1-2-4-2, making a diode conversion matrix necessary to perform the conversion. Figure 4-20 shows the matrix.

As shown, when $\overline{Q}$ is a "0" the drive transistor, Q_B, is turned on, Q_A turns on and connects E_{IN} to the leg of the ladder. If $\overline{Q}$ is a "1", Q_B is off, making the bases of Q_A and Q_G negative. Q_A is then off, and Q_G is on, connecting that leg of the ladder to ground. The diodes convert the digital weighting from 1-2-4-8 to 1-2-4-2.

4.4.6 Leakage-Current Circuit (Figure 6-15).

The leakage-current circuit (L board), an available accessory, measures the leakage current through a capacitor under bias. Figure 4-21 shows a functional block diagram of the circuit and its associated circuits. The circuit consists of an amplifier, comparator, and gate section. When the instrument is in the LEAKAGE mode, relay K on the Y divider board and transistor switch Q5-Q6 on the T board open. This shuts down the bridge and disables the oscillator. K3 on the L board closes, allowing leakage current to flow into amplifier IC1, which converts the current to a voltage. Figure 4-22 shows an equivalent circuit of the measurement network and the amplifier.

The current can be measured in five ranges by changing the feedback network of the amplifier with the front-panel LEAKAGE control. Table 4-3 lists the magnitude of each range and the feedback network for each range. The "Switch" column designates the transistor switch or relay that switches in the applicable components.

The appropriate $\overline{ZLEAK2\text{-}5}$ signal is "0" when the applicable range is selected with the LEAKAGE selector (front panel or external control). If the LEAKAGE switch is set to REMOTE, gates on the Q board are enabled, allowing signals $\overline{ZLEAK2\text{-}5}$, ZLEAK, and LEAKOFF to be applied through the AUXILIARY socket from peripheral equipment if desired. Signal LEAKOUT, a 0-to-2.5-V signal, can be fed through the AUXILIARY socket for measurement by a meter, if desired. The voltage of this signal is proportional to the leakage current on each range. For example, 0.5 V equals 0.5 μA, 5 μA, 50 mA, etc.

Amplifier IC1 has a one-to-one current-to-voltage ratio. For example, for 0.5 μA there will be a 0.5-V output. (The output is a negative voltage.) The dc gain of the amplifier equals R_F/R_S, and the output will swing at TP1 between 0 and −2.5 V on each range. This voltage is compared by IC2 with a preset reference voltage (ZLEAK) selected by the front-panel LEAKAGE 0–2.5 control or applied externally

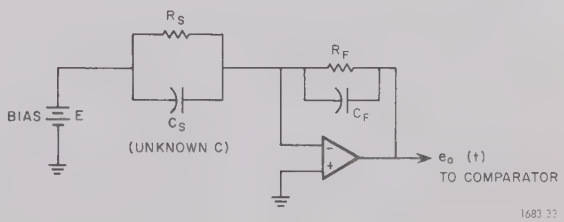


Figure 4-22. Equivalent circuit.

through the AUXILIARY socket and Q board when the instrument is in remote operation.

IC2 is a comparator. If the leakage voltage does not exceed the preset voltage, LGO will go to "1". The voltage at the input to the comparator is positive in the initial state due to the positive reference voltage, ZLEAK. The output of IC2 is "0" and the NO-GO indicator is turned on. As soon as the leakage-current measurement is started, $\overline{\text{PSTL}}$ from the start circuit on the P board goes "0" for a short time and inhibits any transients due to relay "bounce", PLEAK from flip-flop IC28 on the P board also goes to "0" for a short time when a leakage measurement starts, to reset the "go" flip-flop to "no-go". (When leakage is being measured, signal $\overline{\text{ZLEAKOFF}}$ on the Z board disables the gates to the "go" flip-flop.)

Upon application of bias, the input to IC2 goes negative when K3 closes; the junction between R11 and C9 goes negative then starts to return exponentially to a level determined by the leakage current. The negative voltage causes the output of IC2 to go to "1". If the leakage voltage is equal to or exceeds the 0-V level (see Fig. 4-23), a "0" will be produced at the output of IC2, producing a "1" LGO signal that will turn on the GO indicator ($\overline{\text{PLEAK}}$ and $\overline{\text{PSTL}}$ having returned to "1" before this time). If the voltage due to the leakage current does not exceed the reference, the output of IC2 will remain "1" and the NO GO indicator will remain lighted.

The reference voltage is applied according to the limit established with the LEAKAGE control. Figure 4-23 illustrates the typical waveforms at test points TP1 and TP3 at the input to IC2.

The rate of the leakage-current measurement is determined by the setting of the front-panel VARIABLE MEAS. RATE control. A capacitance measurement occurs right after a "go" indication, the negative-going LNG signal having initiated a start pulse on the P board. If a "no go" indication remains, the capacitance measurement occurs at a time determined by the VARIABLE MEAS RATE control. Signal REMGO is applied through the AUXILIARY socket for driving an external indicator or equipment if desired, when measuring externally applied leakage current. Figure 6-15 illustrates the circuit operation when measuring externally applied leakage current.

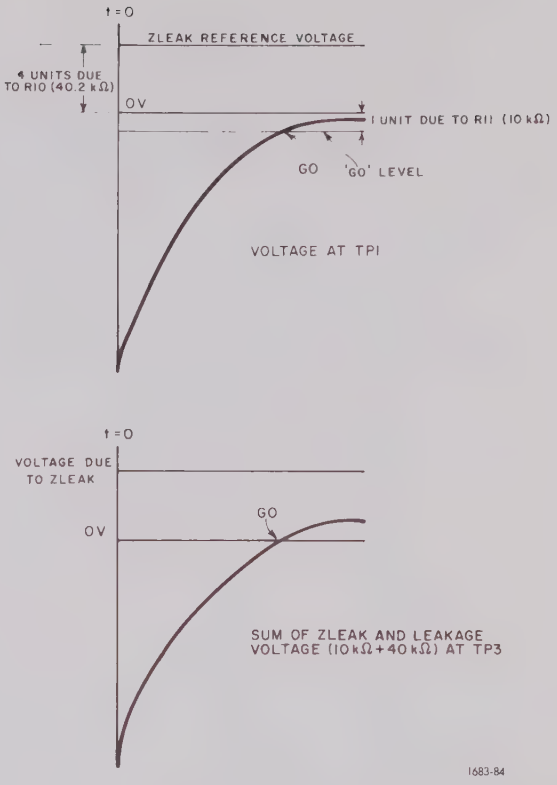


Figure 4-23. Voltage waveforms.

4.4.7 Mother Board (Figure 6-18).

The mother board (M board) occupies the bottom position in the instrument (Figure 5-5) and serves as an intraconnecting assembly for all the circuit boards and a mounting device for the standards. The circuit boards plug into sockets mounted on the mother board; etched conductors on the board carry the signals between the boards. The standards mounted on the board are the capacitor standards C_S and C_B and resistor standards G_S (R_1), G_B (R_2) and G_T (R_3) and associated circuitry, as well as relays K2-K7 and their drivers, Q1-Q6, that switch in the applicable standards for measurement and applicable capacitors for the 120-Hz and 1-kHz measurement frequencies.

Capacitors C5-C14, used with standards C_S and C_B, provide trimmers for the standards, to increase the accuracy to .01%. The inverters (IC1 and IC2), transistors (Q1-Q6), and relays are connected in such a manner that signals ZS2 and ZS3 switch in the applicable standards for F and H measurements and capacitance for 120-Hz or 1-kHz measurements.

Signals ZS2 and ZS3 are produced by the front-panel function control or from externally supplied signals ($\overline{\text{LR}}$ and $\overline{1000}$, respectively). Table 4-4 lists the logical levels of ZS2 and ZS3 for each selected function. The table also shows the state of the relays for each function. A 1 indicates the relay is energized with its contacts closed. When energized, the relays switch in the standards listed in the table, under the applicable relay.

Error signal MD is then applied to the detector circuit. Paragraph 4.2 contains a description of how error signal MD is produced.

Signals routed through the mother board can be traced using the etched board layout and the signal run list. Refer to Section 6, if necessary, for a description of how to trace signals.

Table 4-4
MOTHER BOARD RELAY SWITCHING

Function	Logic Signals		Relays*						
	ZS2	ZS3	K1	K2	K3	K4	K5	K6	K7
LsRs 120 Hz	"1"	"0"	1	1	0	0	0	0	1
LsRs 1 kHz	"1"	"1"	1	0	1	0	0	0	1
CsD 120 Hz	"0"	"0"	0	1	0	1	1	0	0
CsD 1 kHz	"0"	"1"	0	0	1	1	0	1	0
CsRs 120 Hz	"0"	"0"	0	1	0	1	1	0	0
CsRs 1 kHz	"0"	"1"	0	0	1	1	0	1	0
			A 1 Switches In:						
			G_T	C_S	C_S	G_B	C_B	C_B	G_S
			(R3)	(C1)	(C1)	(R2)	(C1)	(C2)	(R1)
				C10	C12		C5	C7	
				C11	C13		C6	C8	
					C14			C9	

*A 1 for the relay condition indicates that the relay is energized.

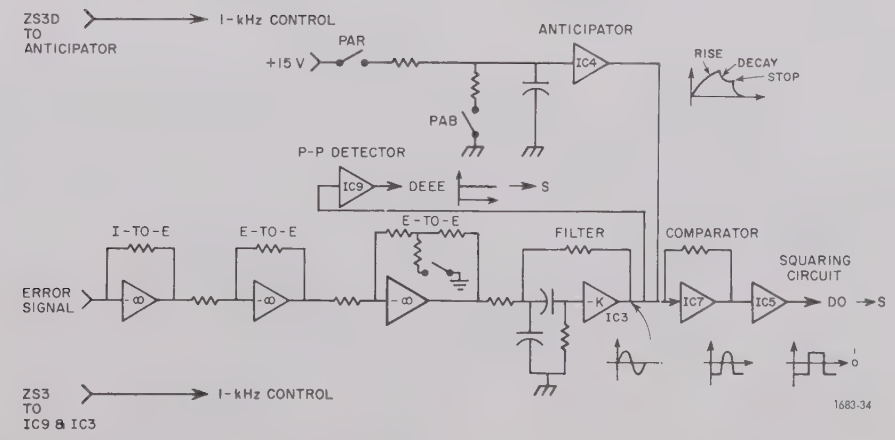


Figure 4-24. Detector circuit block diagram.

4.4.8 Detector Circuit (Figure 6-7).

General. The detector circuit (D board) consists of four major sections:

1. Preamplifier
2. Anticipator
3. Comparator
4. Peak detector.

Figure 4-24 shows a block diagram of the circuit. The preamplifier section converts the current to a voltage, amplifies the voltage, filters the signal, and applies the signal to the comparator.

The error signal is applied to a peak detector that produces an output level proportional to the error voltage. The resultant level, DEEE, is fed to the S board, where the signal is used to indicate if an error is less than 500 counts or 100 counts and thereby control accordingly the rate of the reference clock, SVCO.

The output of filter IC3 is added to the anticipator function and amplified by IC7. IC5 squares the output of IC7. The resultant logic levels control the phase detector flip-flops on the P board.

The anticipator is a floating null that works to minimize the effects of time delays in the servo loop described in paragraph 4.2. The anticipator is driven by the anticipator driver on the P board. This circuit is in turn driven by the direction control flip-flops and the START signal (either the one produced by the front-panel START pushbutton, and external source, or automatically produced on the P board at the start of a new balance). The anticipator causes the bridge to balance more rapidly than conventional methods allow. This is done by producing a signal that compensates for the time delay encountered by the error signal when passing through the preamplifier and filter.

The signal produced by the anticipator simulates the point at which a zero crossing of the error signal would occur had there been no signal delay produced by the preamplifier. The anticipator signal is then added to the error signal and fed to the comparator. It is also fed to the small circuit board on the bottom of the mother board to prevent a slower clock from occurring while the 21 counter is counting. (Refer to para. 4.4.9.)

Preamplifier. The preamplifier consists of four cascaded amplifiers, Q1-Q3 and IC1 and IC3. The overall phase shift produced by the amplifier (output of IC3) is 180°. The first stage converts the error current to a voltage. The second stage, IC1, has a gain of approximately 20 for inductance and resistance measurements and 30 for capacitance measurements. Diodes CR2 to CR7 and CR23 and CR24 limit the output swing of each stage, so that the amplifiers will not saturate. The output of the filter is also fed to a peak detector that provides an early error signal (DEEE) to the reference board for regulating the rate of the clock reference signal (SVCO) for an error indicative of less than 500 or 100 counts of error. This peak detector is similar to those on the reference board. Refer to paragraph 4.4.9 for a description.

The third stage of the amplifier, IC1, is similar to the second stage. The transfer impedance of the three stages is approximately 2 MΩ. The gain of the last stage, IC3, is approximately 5.

IC3 is part of an active filter. The bandwidth of the filter is 0.2 f_o, where f_o is the bridge frequency, 120 Hz or 1 kHz. The Q of the filter is approximately 5.

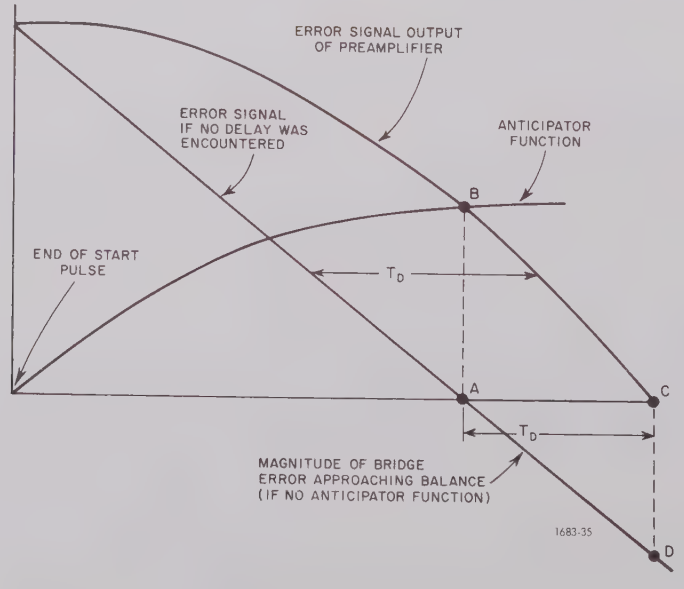


Figure 4-25. Anticipator function.

Potentiometers R41 and R42 are for correcting the phase shift produced in the previous stages. C20 and C18 are switched out by signal ZS3, for 1.0-kHz measurements.

Anticipator. The comparator circuit will produce signals that ultimately control the counters. To obtain a true null when the magnitude of the error signal in the bridge reaches zero, a signal must be introduced to compensate for time delay that occurs as the error signal passes through the preamplifier. Figure 4-25 shows how the anticipator produces this compensation signal. The straight sloping line shows the signal out of the preamp if no delay occurred. The downward-sloping curved line shows a typical error output with delay. The line between points A and C, T_D, shows the delay.

If the bridge were stopped at point C where the level is 0 V, the bridge error would not be at zero but at point D. It is, therefore, necessary to stop the bridge at point B, since this is where the bridge error is actually at zero. To do this, a signal is produced by the anticipator that will anticipate where the bridge should be stopped, taking into account the time delays (T_D) between the bridge error signal and the point at which it is sampled. The anticipator function rises at the end of the start signal, until a stop is indicated by both of the direction control flip-flops on the P board. These flip-flops help control the main gates on the E board that gate clock pulses to the 1I and 2I counters. Paragraph 4.4.10 describes when these flip-flops indicate a stop. The function then decays during a stop, no counting is done during this period. If the anticipator function (level) decays to a point where the bridge error exceeds that prescribed by the anticipator function level, a control signal, DO, will be produced. Although described in detail in the following paragraph, it should be mentioned that the output of filter IC3 is added to the anticipator level in summing-amplifier IC7. If the filter output exceeds the null level of the amplifier at certain phase points, the control signal (DO) will be produced to drive the direction flip-flops on the P board. As the anticipator level drops, samples are taken, and if the filter signal exceeds the null level of the amplifier at these certain points, the anticipator will be commanded to hold while counting begins again. When a balance is approached, the anticipator level will drop again and samples will be taken again. If the signal from the filter again exceeds the amplifier null level, the anticipator will hold while a count is made. The process repeats until the anticipator level decays to the point where a null (or balance) occurs.

Figure 4-26 shows a simplified block diagram of anticipator generator and a typical exponential function produced by the generator. The exponential function is determined by C14, C15, R21 and R22. C14 is switched by signal $\overline{ZS3D}$ when 120-Hz measurements are being made. FET's having low leakage current are used to provide a good holding circuit. Table 4-5 lists a typical operational

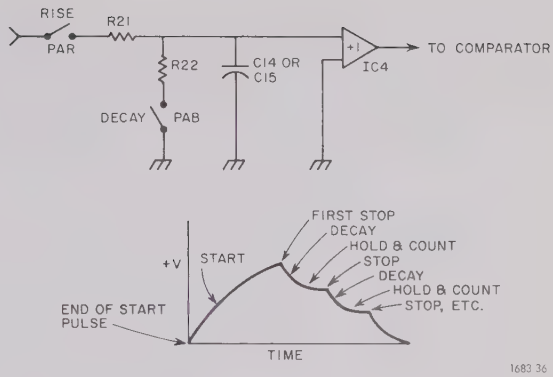


Figure 4-26. Simplified schematic of the anticipator generator and a typical function produced.

sequence. When the anticipator signal is greater than the preamplifier error signal, the comparator output is at ground. When the error signal is less than the anticipator signal, the comparator output is a "1".

Paragraph 4.4.10 gives details on the generation of the PAR and PAB signals.

R30 is a zero adjustment and R81 is a current-offset adjustment.

Comparator. The comparator consists of IC7, IC5, and Q13. IC5 adds the output of the filter to the anticipator output. Under certain conditions described further on in this paragraph, IC7 produces an output that is converted to a square wave by IC5. This produces a 5-V signal at the output of Q13. To better understand the operation of this circuit, a typical operation is as follows.

Table 4-5
ANTICIPATOR FUNCTION

Sequence	PAB	PAR	Notes
Rise	0	1	Starts rising when START signal goes to "1"
Decay	1	0	Counters off
Hold	0	0	Counting begins
Decay	1	0	Counters off
Hold	0	0	Counting begins

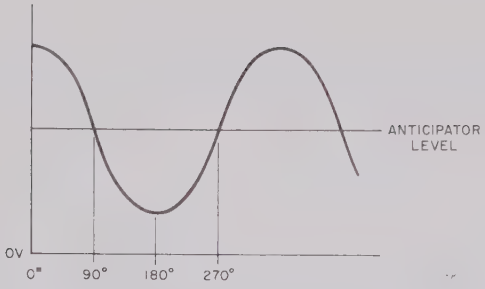


Figure 4-27. Input to IC7.

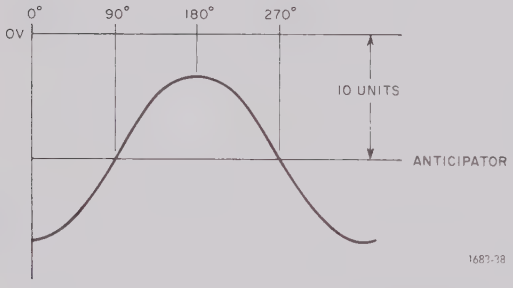


Figure 4-28. Output of IC7 (near balance).

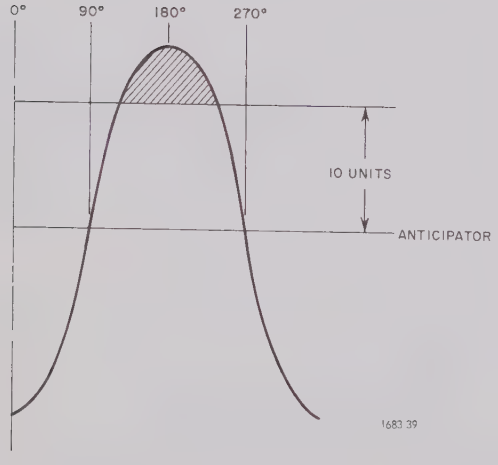


Figure 4-29. Output of IC7 (unbalanced).

The output voltage of the K divider (refer to Figure 4-12) should be a negative sine wave and I_{Cs} (i_b) should be a negative cosine; the resultant output of the filter ($IC3$) is a positive cosine. The voltage output of the B board is a negative sine wave and I_{Cs} a negative sine wave; the resultant output of the filter is a sine wave. Therefore, a positive cosine implies a high α output and the 1I counter should count reverse; a negative cosine implies a low α output and the counter should count forward. A positive sine wave implies a high β output and the 2I counter should count reverse; a negative sine wave implies a low β output and the counter should count forward.

Signal DO will be a "1" if the sum of the anticipator level and the error signal is less than 0 V. Signal DO is sampled on the P board by the 0°, 90°, 180°, and 270° phase-sampling flip-flops that determine the direction the counters should be counting, or if they should be stopped. The applicable flip-flop is set when DO is "1". Paragraph 4.4.10 describes this operation and the resultant state of the counters (counting forward, reverse, or stopped).

IC7 adds the output of the filter to the anticipator signal and inverts the resultant signal. Take the example of a cosine applied to IC7 from the filter. Figure 4-27 shows a cosine riding on the anticipator output, which is shown as an idealized level (actually it would be varying up or down and/or holding). In Figure 4-28 the signals imply a case where the bridge is near balance, since the magnitude of the signal does not exceed the null level. Figure 4-29 shows the case where the cosine exceeds the null level. (Note that before inversion by IC7, the sum of the anticipator and filter signals is less than 0 V and hence a "1" DO signal is produced.) When the error signal exceeds the anticipator level, IC5 goes to a "0" level, producing a "squared" signal that is inverted by Q13. The output is therefore a 5-V level. Figures 4-30 and 4-31 show these waveforms.

Figure 4-32 shows the input to IC7 near balance (null). Note that a phase shift occurs when the error signal goes through a null. All the waveforms presented in this paragraph are idealized.

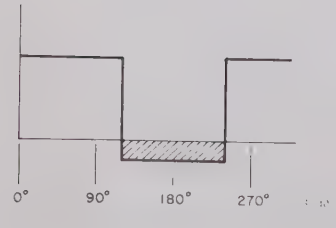


Figure 4-30. Output of IC5.

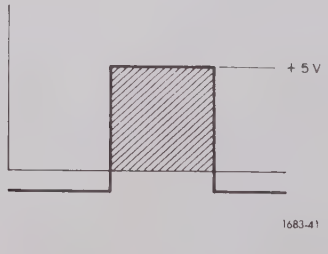


Figure 4-31. Signal DO.

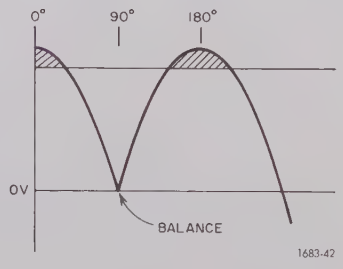


Figure 4-32. Balance.

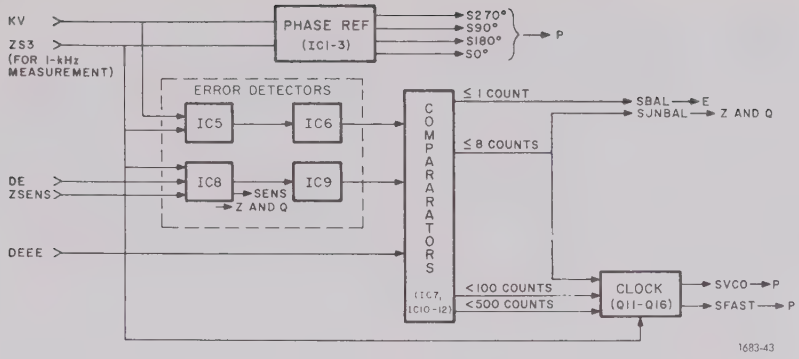


Figure 4-33. Reference circuit block diagram.

4.4.9 Reference Board (Figure 6-22).

General. The reference board (S board) has the following functions:

1. Provides 0°, 90°, 180°, and 270° phase-reference signals to the direction-control circuit on the program board, for determining the direction that the 1I and 2I counters should count (forward or reverse), or if they should stop counting.
2. Provides a signal via the Z board to the front-panel UNBALANCED indicator that will light the indicator while the bridge is unbalanced.
3. Determines from a reference signal and from error signals the range of error (counts), if any, exists at any given time.
4. Provides a clock signal whose repetition rate varies according to the magnitude of the bridge error. The signal eventually drives the 1I and 2I counter and the range counter in the range circuit (E board).

Figure 4-33 shows a detailed block diagram of the circuit. As shown, the circuit is comprised of a phase-reference circuit, error detectors, comparators, and clock.

Phase-Reference Circuit. Refer to Figure 4-34 and the schematic for the following description. Signal KV is the bridge reference signal from the K-divider board. This signal is amplified by IC1 and limited by Q1 and Q2. IC4 is a comparator amplifier that senses zero crossing of a signal. The comparator, therefore, produces a square wave in phase with the reference signal, KV. R3, R4, C2 and C4 form an integrator that provides a 90° phase shift of the signal, which is amplified by IC2. IC3 is a comparator that senses the zero crossing of a signal and produces a square wave 270° out of phase with the reference signal. C3 and C5 are switched in to the circuit when making measurements at 120 Hz.

Error Detectors. The error detectors consist of peak detectors (IC5 and IC8) and buffer amplifiers (IC6 and

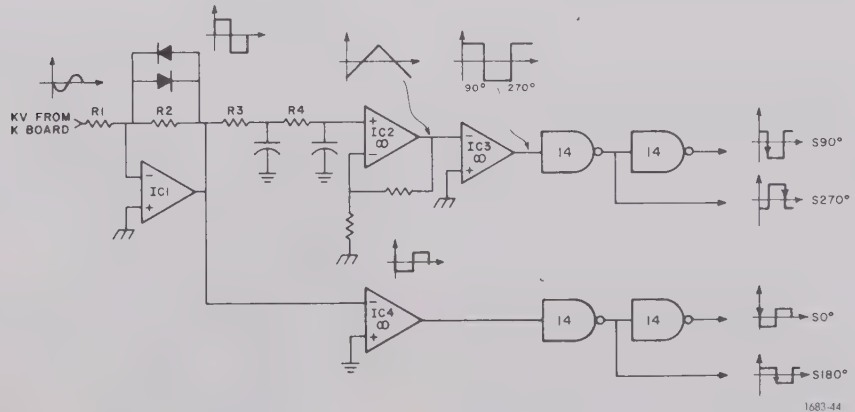


Figure 4-34. Phase-reference circuit.

IC9). Peak detector IC5 and its buffer amplifier, IC6, operate as follows: When the input signal, KV, goes negative, CR6 conducts; therefore, the amplifier has zero gain. As the input goes positive, CR5 conducts, and the gain is proportional to R20/R19. R21, C14, and C15 filter the output signal; the effect is a negative dc level proportional to the positive peak value of KV. IC6 is a buffer. C15 is also switched in for 120-kHz measurements, so that charging time is constant with frequency. The output of the buffer amplifier is given by

$$E_o\,(dc) = \frac{R20}{R19}\ \frac{1}{\pi}\left(1 + \frac{R104}{R102}\right) l\ \text{KV (peak)}.$$

R22 is for adjusting the zero level of amplifier IC5. The output is applied to a comparator circuit which compares this reference level to the bridge error.

The circuit that processes the DE signal operates in the same manner, except the output level is positive. The signal is also proportional to the error voltage, DE. The front-panel SENSITIVITY control allows for reduction of this voltage to overcome noise or other interference. At maximum sensitivity the error is one count or less; less sensitivity can be 8 counts or less, 100 counts or less, etc. The sensitivity can also be programmed externally by programming a resistance between the AUXILIARY socket SENS signal connection and YGL ground connection. Refer to paragraphs 4.4.13 and 3.11 for more information concerning this type of operation.

Comparators. IC7, 10, 11 and 12 are comparators that compare error signal DE and early-error signal DEEE to the reference signal. If the error is less than 500 counts, IC12 produces a "1" output that slows the clock rate. If the error is less than 100 counts, IC11 produces a "1" output that is also applied to the clock circuit to further slow down the clock rate. If the error is less than 8 counts, then IC10 produces a "1" that is inverted and applied to the clock circuit for slowing the rate and to the UNBALANCED lamp, extinguishing the lamp.

Because of low sensitivity on the 2I(R)-side counter when measuring capacitance that is less than full scale, it is necessary to prevent a slower SVCO clock from occurring while the 2I side is still counting. A gate circuit mounted on a small board underneath the mother board helps to slow the clock when the anticipator signal at the D board and reference signal from the S board are at certain states. A flip-flop in this circuit is set whenever the reference signal and anticipator signal indicate an error of 8 counts. The output of the flip-flop turns on the slowest clock. When the ancicipator level indicates a balanced condition, an amplifier produces an output to the S board that is applied to the output of inverter of IC7 (error 1 count or less comparator), that in addition to IC7, also produces signal SBAL. (See Figure 6-21.) Refer to paragraph 3.10.1 for further information concerning 2I-side counter sensitivity.

A slower balance may occur when making a low-capacitance high-loss measurement.

When the error is determined to be one count or less, IC7 produces a "1" that is "ANDED" on the E board with other signals (direction control and change range) to produce signal EBAL that is fed to the P board to produce a bridge-balanced signal that disables the counter clocks and produces a balance start-pulse.

R40-R43 are for adjusting the comparators. SFAST, from comparator IC12, is fed to the anticipator-driver circuit on the P board to indicate that a fast count is in process, preventing an anticipator-function decay signal from occuring immediately after the main gates are inhibited. (Refer to paragraph 4.4.10.)

Clock. Clock signal SVCO is a 5-V, 0.5-μs pulse that produces the PLCK23 and PLCK12 clock signals at the P board that drive the 1I and 2I counters and the range counter on the E board. SVCO is produced by Q11 and Q16 and the output IC gates. The rate of the clock depends on capacitors C24-C27 that are switched in by the comparator outputs when a certain count is detected; the greater the error the faster the clock rate.

Q21, Q14, R64 and R65 form a current source that charges C24-C27 toward −15 V from +15 V. Signal ZS3 acts to cut off Q14 a 120-Hz measurements, reducing the flow of source current to approximately 0.5 mA. At 1 kHz the transistor pair (Q14 and Q21) supplies the current.

The base of Q15 is approximately 6.9 V. As the voltage at the emitter of Q15 drops to approximately 6.3 V due to the capacitor(s) charging toward −15 V, Q15 turns on, turning on Q16. The capacitors then charge toward +15 V through the Q15-Q16-R68 path until the point between R69 and R70 rises from approximately 6.9 V to 12 V, in approximately 0.2 μs, turning off Q15 and Q16 and causing the capacitors to again charge toward −15 V. C29 acts as a differentiator, applying the pulse to the IC gates. As the error decreases, the comparators switch more capacitors into the charging circuit. The time between the charging to +15 V is given by $\Delta T = \frac{C\Delta E}{I}$.

Table 4-6 gives the frequency for 120-Hz and 1-kHz measurements for various error conditions.

4.4.10 Program Board (Figure 6-18 and 6-19).

General. Figures 4-35 and 4-36 show a block diagram of the program board (P board). The program board contains the following circuits:

1. Clock-pulse circuit
2. Variable-measurement-rate generator (PVMR)
3. Direction-control flip-flops
4. Anticipator-driver gates
5. Balance flip-flop
6. No-balance delay
7. Start pulse

8. Anti-bounce switch
9. Counter test-control logic.

From the control oscillator signal (SVCO), the clock pulse circuit produces clock pulse PCLK23 that drives the range counter and main gates on the E board, pulse PCLK12 that drives the range-delay circuitry on the E board and activates the main gates that gate the clock pulses that drive the 1I and 2I counters, and pulse $\overline{\text{PCLK12}}$ that "interrogates" the direction-control flip-flops on the board.

The PVMR generator produces start pulses for a balance operation when the instrument is in the variable measurement or remote modes of operation. The generator will also produce a start pulse for a capacitance measurement after a leakage measurement is completed. When the front-panel switch is set to any TEST position, the SVCO clock input is disabled. The generator then produces clock signals PLCK12, PLCK23, and $\overline{\text{PCLK12}}$, with rates that can be varied by the front-panel VARIABLE MEAS RATE control. Also in this mode, the program circuit produces a "1" $\overline{\text{PRIG}}$ signal that holds the main gates on the E board turned on, allowing the counter clocks to remain on even if the bridge is balanced. This allows testing the range circuitry and counters.

When the mode switch is set to TRACK, the generator is free-running, but the generator signals are not used. In this mode, however, the program circuit also produces a "1" $\overline{\text{PRIG}}$ signal that holds the main gates on the E board turned on, allowing the counter clocks to remain on even if the bridge is balanced.

In the variable-measurement-rate mode of operation, the generator is inhibited during an unbalanced condition and turned on after the bridge has balanced, to produce a start pulse for the next balance. In the test or track modes, the generator is not inhibited during an unbalance condition. Also, if a leakage measurement is being made, the generator will be turned on to produce a start pulse for a capacitance measurement that follows, even if the bridge is in an unbalanced condition.

When measuring leakage current in the variable-measurement or single-measurement modes, the generator is turned on at the beginning of the leakage-current measurement, as described above. The PVMR generator pulse rate is slowed, however, so that sufficient time (up to 10 s) will be allowed before the generator produces a start pulse for a capacitance measurement. (If a leakage-current condition is found to be acceptable before the allotted time, the leakage circuit will produce a signal that initiates a start pulse — not by the PVMR — for a capacitance measurement that follows.)

The generator can be inhibited by an external 0-V INHIBIT signal applied to the DATA-OUTPUT socket (routed via the Q board).

The direction control flip-flops produce the signals (PRR, PIR) that command the 1I and 2I counters to count forward or reverse (Figure 4-36). This is done by applying error signal DO, a "squared" signal, to the flip-flops and then strobing the flip-flops with 0°, 90°, 180°, and 270° reference signals from the S board. $\overline{\text{PCLK12}}$ then "interrogates" the information stored in the flip-flops, to control the direction in which the counters must operate to achieve a balance. These flip-flops also produce signals $\overline{\text{PRG}}$ and $\overline{\text{PIG}}$ that disable or activate the main gates on the E board that pass clock signals to the counters. The anticipator-driver gates produce signals PAB and PAR that cause the output of anticipator generator on the D board to rise, decay, or hold, according to the point at which a balance is close to being achieved; i.e., a balance operation started and bridge not close to balance means a rise (after a time delay after START pushbutton is pressed), balance is being achieved means decay, counting is being done means hold.

When the bridge is balanced and the instrument is not in the track or test modes, the balance flip-flop circuit disables the signal $\overline{\text{PRIG}}$ that activates the main gates on the E board and, therefore, the clock (PCLK12) that drives the counters. The circuit also produces signal PBUSY when the bridge is in an unbalanced condition, to indicate to peripheral equipment that the bridge is attempting a balance. This signal is fed to the Q, N, and J boards. On the J board it keeps bias supplied to the part under test until a balance is achieved. Also, if the bridge is not balanced within 2.5 s after a start pulse is generated, signal $\overline{\text{PABORT}}$ is produced by a time delay circuit (no-balance delay) associated with this flip-flop. This signal is fed to the N board and the DATA-OUTPUT connection to indicate that a "null" has not been achieved. When leakage-current is being measured, the ABORT signal is inhibited by the 'A' output of F-F IC28, which is applied to the time delay circuit.

The start-pulse circuit produces the $\overline{\text{PSTART}}$ pulse that starts the anticipator generator and, hence, the bridge balancing operation. The pulse can be produced five ways:

1. By pressing the START pushbutton switch on the front panel (ZSTART).
2. By an external closure ($\overline{\text{NSING2}}$) to ground applied through front-panel EXT START connector.
3. By a single-measurement pulse ($\overline{\text{NSING}}$) produced by an external electronic closure to ground applied to the applicable pin connection on the AUXILIARY socket or DATA-OUTPUT socket.
4. By the PVMR generator at a delayed time after a previous balance is achieved.
5. From a signal (LNG) from the L board that indicates leakage current is acceptable. (This can occur during the period allotted for a measurement and not necessarily at the end of the period.)

This circuit also produces two signals that start leakage measurements, $\overline{\text{PLEAK}}$ and $\overline{\text{PSTL}}$. It also produces a signal $\overline{\text{PLEAKOFF}}$ that opens relays on the Y board, gates off the oscillator on the T board, enables the leakage amplifier on

Table 4-6
CLOCK FREQUENCY

Condition	f/fo	1 kHz	120 Hz
500 counts < Error	500	500 kHz	60 kHz
100 counts < Error < 500 counts	50	50 kHz	6 kHz
8 counts < Error < 100 counts	5	5 kHz	600 Hz
1 count < Error < 8 counts	0.5	500 Hz	60 Hz

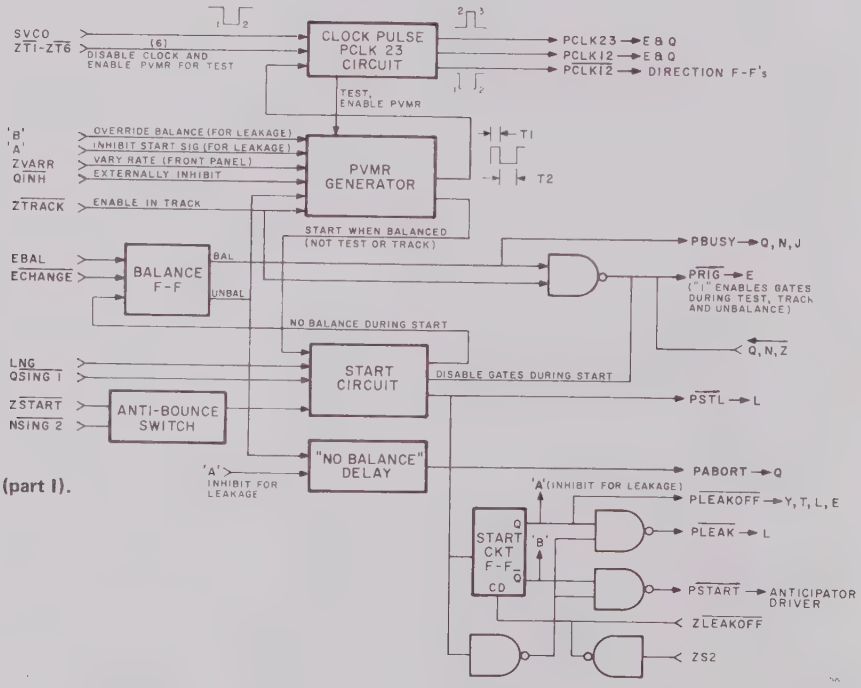


Figure 4-35. Program circuit block diagram (part 1).

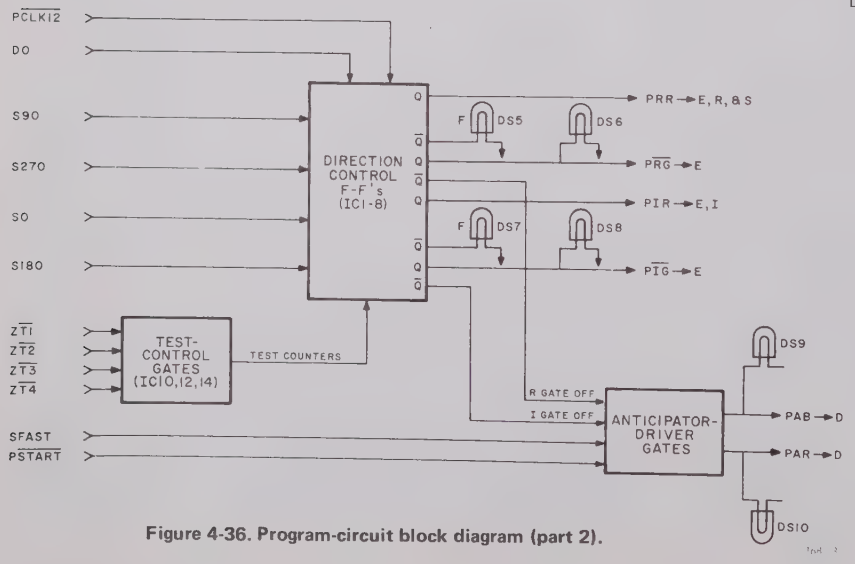


Figure 4-36. Program-circuit block diagram (part 2).

the L board by connecting the amplifier through a relay closure, and disables the main gates on the E board during a leakage-current measurement.

Clock-Pulse Circuit. The clock produces pulses PCLK12 and PCLK23, as shown in Figure 4-35. These pulses are time related; PCLK12 is 1μs, PCLK23 $\approx$ 340 ns. SVCO, a clock whose rate is proportional to the error signal, drives the clock. If the mode selector is set to any TEST position, a "0" is applied to pin 4 of IC23, which disables the SVCO input. A "1" is applied to pin 12 of IC23, allowing the PVMR generator to drive the clock.

PVMR Generator. The PVMR generator drives the clock when the instrument is in any test mode of operation. In the track mode the PVMR operates continuously.

If Q8 and Q21 are turned off, the generator will start to operate. This occurs when in the test or track modes of operation and when a $\overline{\text{QINH}}$ signal ("0") from an external source is ***not*** applied to the instrument, when the instrument in any other mode of operation and the bridge has been balanced, or when a leakage-current measurements is being made in the variable measurement rate mode.

Initially, the junction between C1 and C2 is at +10 V. This is applied to the base of Q5,turning it on because Q4 is off, +6.66 V being applied to its base. Since Q4 is off, Q3 and Q6 are off. Q7 is therefore off, and the +5 V at its collector is inverted, producing a "0" level PVMR signal. The signal at the junction of C1 and C2 charges in the negative direction through R7 and the front-panel VARIABLE MEAS RATE potentiometer towards −15 V. The discharge time is determined by these resistors and C1 and C2. C1 is switched in when a leakage-current measurement is being made (see input 'A' from flip-flop IC28 in the start-pulse circuit).

This slows the generator, producing an output pulse that can be varied according to the periods listed in Table 4-7. When the capacitor(s) discharges to approximately 0 V, Q5 is turned off and Q4 turns on, turning on Q3 and Q6. Q6 turns on Q7, producing a "1" at the pin-10 output of IC10. C1 and C2 charge up toward +15 V through the path comprised of R8, CR4, Q3, R49, and R13. When Q3 is turned on, 10 V is applied to the base of Q4, holding it on. When the junction of C1 and C2 reaches +10 V, Q5 turns on, turning off Q4, Q3 and Q6. The cycle then repeats. Table 4-7 lists the charging (T2) and discharging (T1) times for various conditions.

As mentioned above, Q8 and Q21 activate or disable the PVMR generator. The generator is activated when a "0" is applied to the bases of Q8 and Q21, turning them off. This occurs when the mode selector is set to any TEST position, or to the TRACK position, and a "0" $\overline{\text{QINH}}$ signal from an external source is not present, or when a leakage-current measurement is being made in the single-measurement mode, or when the instrument has reached a balanced condition in the VMR mode. In the VMR mode of operation the PVMR generator is shut off until a balanced condition is obtained, after which Q8 is turned off by the balance circuit F-F, and the PVMR generator starts running to produce a signal $\overline{\text{PSTART}}$ (provided that an inhibiting $\overline{\text{QINH}}$ signal is not applied to pin 10 of IC25). If a leakage-current measurement is to be made in this mode, however, a "1" input at pin 5 of IC30 from the Q side of IC28 will allow the PVMR generator to operate during a leakage measurement, overriding any unbalanced condition that would turn off the generator.

In the variable measurement mode of operation, a "0" ZVAR signal is applied to pin 5 of gate IC26, producing a "1" that gates on the PVMR generator output to produce a start pulse, indicating the start of a balance.

If a leakage-current measurement is being made, however, the 'A' input ("0") also allows a start pulse generated by the PVMR in the single measurement mode to be gated out for a capacitance measurement, after the leakage measurement has been made.

Start Circuit. The start circuit is activated by the negative-going edge of an input pulse applied to any input of IC27. This occurs under any of the five following conditions:

1. PVMR pulse goes to "1" and gate IC25 is enabled during the variable measurement mode, and a leakage-current measurement is not in process.
2. The external single measurement electronic start signal $\overline{\text{QSING1}}$ goes to "0".
3. The front-panel START switch is pressed, producing a "0" $\overline{\text{ZSTART}}$ signal that in turn produces a "0" output from the anti-bounce switch when $\overline{\text{ZSTART}}$ returns to "1".
4. A "0" external $\overline{\text{NSING2}}$ signal is produced at the front-panel EXT START jack, or a closure to ground is produced at pin 49 of the DATA-OUTPUT socket, which in turn produces a "0" output at the anti-bounce switch when $\overline{\text{NSING2}}$ returns to "1".
5. A negative-going LNG signal from the L board, producing a start pulse for a capacitance measurement

Table 4-7
PVMR GENERATOR RATES

T1	T2	VARIABLE MEAS. RATE Sw.
5 ms	2 ms	FAST
15 ms	1.5 s	SLOW
60 ms	20 ms	FAST*
200 ms	12 s	SLOW*

*Leakage-current measurement

after an acceptable leakage-current condition has been found before the full time allotted for a leakage-current measurement.

The inputs to IC27 from the anti-bounce switch circuit and the PVMR generator are differentiated, going from approximately +4 V to 9 V on a "1" input and from approximately +4 V to 0 V on at a "0" input. When a "0" appears at any of the inputs to IC27, the resultant "1" output is inverted and clears the balance flip-flop to the "unbalanced" state, producing signal PRIG that enables the main gates on the E board and disables the PVMR generator. Signal $\overline{\text{PSTL}}$ is also produced to start a leakage measurement, if the instrument is measuring leakage current. If the instrument is in this mode of operation, $\overline{\text{ZLEAKOFF}}$ and ZS2 will allow flip-flop IC28 to be set, producing a $\overline{\text{PLEAK}}$ signal that is fed to the L board to start the leakage circuits. It will also produce $\overline{\text{PLEAKOFF}}$ that does the following:

1. Opens relays on Y board, disabling the current divider network.
2. Gates off the oscillator on T board.
3. Enables the leakage-current amplifier on the L board by connecting it through a relay closure to the capacitor under test.
4. Disables main gates on the E board.
5. Disables various circuits on the P board via the flip-flop 'B' output, described previously in this paragraph.
6. Indicates to external recording equipment that a leakage-current measurement is being made.

The duration of the start pulse (15 ms) is determined by the timing circuit comprised of C9 and R29. A negative-going LNG signal indicates an acceptable leakage measurement has been completed and produces a start pulse for a capacitance measurement. If a "no-go" leakage-current condition exists, the start pulse will be produced by the PVMR generator after a delay. $\overline{\text{PSTART}}$ is produced any time a start signal is produced except during a leakage-current measurement, in which case the AND gate (IC 24) that produces the pulse is disabled. The pulse is fed to the anticipator-driver circuit, which activates the anticipator on the D board, and to the small board on the bottom of the mother board, to reset the flip-flop on that board. Note that $\overline{\text{PLEAK}}$ and $\overline{\text{PSTART}}$ are gated on according to the start of flip-flop IC28, the state of which determines if a leakage measurement is to be made.

Anti-Bounce Switch. The anti-bounce switch produces a signal that overrides the "0" $\overline{\text{ZSTART}}$ or $\overline{\text{NSING2}}$ "0" level signal by 70 ms to eliminate the signal bouncing that is produced by noisy contact closures. If not eliminated, this unstable condition may cause erratic gating of signals. When both inputs are "1", Q15 is turned on. The collector of Q15 is then 0 V. C11 is then charged toward +15 V through R40. Current through R39 will turn on Q13, holding Q14 off. When an input goes to "0", Q15 is turned off, turning off Q13, which turns off Q14. The duration of the output pulse is determined by the time required to charge C11 back to 0 V at the base of Q13.

Balance F-F. The balance flip-flop is set by the start pulse produced by the start circuit and is reset to the balance state when $\overline{\text{ECHANGE}}$, EBAL, and no-start-pulse-is-being-produced are present at its input gates (IC27). $\overline{\text{ECHANGE}}$ indicates a change or possible change of range is necessary. When "0" during a range change, it prevents EBAL from resetting the flip-flop. EBAL is "0" until a balance is achieved and no possible range change can occur. Then it goes to "1", resetting the flip-flop. When set to the "balanced" state, the flip-flop enables the PVMR generator, so that it produces a pulse that in turn produces a start pulse for another balance operation. The flip-flop also disables the main gates on the E board by disabling signal PRIG, causing it to go to "0". If the flip-flop is not balanced within 2.5 s, the "no-balance" delay circuit produces signal PABORT, which is used to indicate to peripheral equipment that a balance has not occurred within the allotted time. The flip-flop is set to the "unbalanced" state by the start pulse.

Direction Control F-F's. The error signal, DO, is a squared signal developed on the D board from the bridge error signal. The phase reference signals from the S board, S0°, S90°, S180°, and S270°, are negative-going signals at the particular phase-reference time and are applied to flip-flops IC1 through IC4, together with error signal DO. The flip-flops are clock-type flip-flops that change state on the negative-going edge of the "T" input pulse (phase-reference signals), if the applicable side is enabled by a logical "1". Note that in the schematic the Q outputs of flip-flops 1 through 4 are labeled GR, GF, CR and CF respectively. The reference signals strobe the flip-flops, which store the direction information. Table 4-8 lists the state of the flip-flops for each condition. The signal DO logic level listed is the level at the input to the P board.

Table 4-8
PHASE-DETECTOR F-F's

GR(IC1) is:	"0" if DO is "1" @ 90° "1" if DO is "0" @ 90°
GF(IC2) is:	"0" if DO is "1" @ 270° "1" if DO is "0" @ 270°
CR(IC3) is:	"0" if DO is "1" @ 0° "1" if DO is "0" @ 0°
CF(IC4) is:	"0" if DO is "1" @ 180° "1" if DO is "0" @ 180°

Table 4-9
F-F AND COUNTER TEST

TEST Sw. Position	DS5	DS6	DS7	DS8
1 1I Counter	—	OFF Disable 2I	ON (F)	ON Enable 1I
2 Check	OFF	OFF Counter	OFF (R)	ON Counter
3 2I Counter	ON (F)	ON Enable 2I	—	OFF Disable 1I
4 Check	OFF (R)	ON Counter	OFF	OFF Counter

Therefore, if DO is a negative cosine, this implies a high α, or reactance, error and the 1I counter should count reverse; if DO is a positive cosine, a low α error, and the 1I counter should count forward. If DO is a negative sine wave, this implies a high β, or resistance, error and the 2I counter should reverse; a positive cosine, implies a low β error and the counter should count forward. A DO "1" level at 90° is a positive sine wave, at 270° a negative sine wave, at 0° a positive cosine wave, and at 180° a negative cosine wave.

The functions to be produced by the next set of flip-flops in the direction circuitry, IC5 through IC8, are forward, reverse, and stop the 1I and/or 2I clocks. (Refer to the table in Figure 6-19.)

Flip-flops IC5 through IC8 are strobed by PCLK12, which is not synchronized with the bridge. Since these are clock-type flip-flops, the negative-going edge of PCLK12 causes the flip-flop(s) to go to the state that is enabled by a "1" at all its gate inputs (S or C). When the instrument is not in the test mode of operation, the flip-flop S and C gate inputs from the Z board ($Z\overline{T1} - Z\overline{T4}$) are "1", i.e., the SD and CD inputs are "1". Therefore, the flip-flops are activated by the inputs from flip-flops IC1 through IC4 and by PCLK12 in the non-test mode of operation. PRR is "1" if GR is "1" when PCLK12 occurs (count reverse) and "0" if GR is "0" at this time. PIR is "1" if CR is "1" when PCLK12 occurs (count reverse) and "0" if CR is "0" at this time. $P\overline{RG}$ is "0" (2I main gate disabled) if GR = GF, and $P\overline{IG}$ is "0" (1I main gate disabled) if CR = CF. Signals PIR and PRR can also be supplied to external equipment via the auxiliary board (Q) for driving the equipment.

Note that the indicator lamps DS1 — DS4 connected to flip-flops IC1-4 light when the flip-flops are in the set state, producing a "1" output at the Q side. Also note that indicators DS5 and DS7, connected to flip-flops IC5 and 7, respectively, light when the flip-flops are in the clear state, indicating a forward count. DS6 and DS8 will be lit when the respective (2I and 1I) flip-flops are set, supplying enabling signals to the clock main gates on the E board. These flip-flops (IC5-8) can be checked by the test mode of operation. Table 4-9 gives the state of the flip-flop lamps for each applicable test position of the front-panel mode switch. The "F" and "R" letters indicate a forward- or reverse-count signal.

This test exercises the 1I and 2I counters, decoders, and displays by causing the counters to count forward and reverse if the instrument is operating properly. The range counter on the E board will also change ranges during the test mode.

Anticipator-Driver Gates. Two signals are produced by this circuit to drive the anticipator generator, PAB and PAR. The anticipator output is the signal that the error signal is compared with. The combinations of the PAB and PAR signals, when applied to the anticipator generator, produce three conditions; (1) a rising signal, (2) a decaying signal, and (3) a holding signal. (Refer to Figure 4-26.) Note that when a balance is obtained and the 1I and 2I main gates are disabled by flip-flops IC6 and IC8, a "1" stop signal is produced at pin 10 of IC15 and pin 13 of IC9. If the instrument is counting at a very fast rate, the SFAST signal from the "error < 500 counts" comparator on the S board prevents a decay signal from occurring immediately after the main gates are inhibited. This prevents a transient from causing a delay. A decaying signal will be initiated when the output of IC15(3), "stop counters", is "1" and

Table 4-10
ANTICIPATOR-DRIVING SIGNALS

Sequence	PAB	PAR	PSTART	STOP
Rise	0	1	1	0
Decay	1	0	1	1
Hold	0	0	1	0

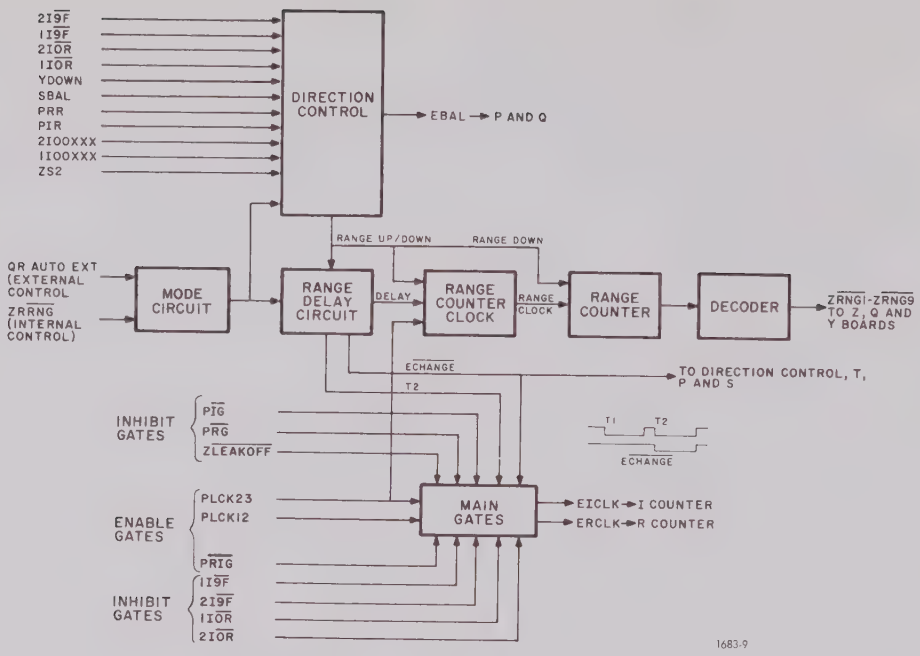


Figure 4-37. Range circuit block diagram.

either SFAST is "0" or "stop" counters has been a "1" for 8 ms (determined by the time delay comprised of Q16 and Q17 and associated parts).

Table 4-10 lists the conditions under which decay (PAB), rise (PAR), and hold signals will be produced. The STOP signals listed are the output of IC9(11). This is not the "start" signal mentioned above but is derived from it.

Note that DS9 lights when PAB is "1" and DS10 lights when PAR is "1".

Counter Test Control Logic. This circuit controls the state of the direction control flip-flop to exercise the counter circuits in the instrument. This circuitry was described earlier in this paragraph.

4.4.11 Range Board (Figure 6-8).

General. The range board (E board) contains the circuitry that produces signals that switch in applicable range resistors on the Y board when a change of range is necessary; changes the front-panel range and decimal point indicators (via the Z board); provides a time delay for the change of range signals, giving the circuits a chance to "settle down"; and provides a signal to the front-panel RANGE indicator that causes the indicator to light, indicating that a change of range may be necessary.

These functions occur when the instrument is set to the automatic (AUTO) or automatic-remote modes of operation. The circuit also contains the main-gate circuit that gates clock pulses to the 1I and 2I counters. This circuit functions during all modes of operation, except during certain conditions in which the gates will be inhibited. Figure 4-37 shows a block diagram of the range circuit. The range circuit consists of the following circuits:

1. Mode
2. Range delay
3. Range-counter clock
4. Direction control
5. Range counter and decoder.

The mode circuit activates the range counter when the front-panel RANGE control is set to AUTO, or when it is set to REMOTE and a 0-V QRAUTOEXT signal is applied to the appropriate pin connection on the AUXILIARY socket. The 0-V QRAUTOEXT signal overrides the remote mode of operation, disabling the gates on the Q board that gate in external range signals ($\overline{RNG1}$-$\overline{RNG9}$) and allowing the 1683 range counter to operate; in remote range operation, the range counter is normally disabled, the range being determined by external signals applied to the 1683.

The direction control circuit has circuits for three functions: (1) down-range counting, (2) up-range counting, and (3) automatic ranging.

When the range circuit is enabled, the automatic ranging circuit activates the down-range counting circuit when the range counter is providing a range indication from range 2 to 9. The up-range counting circuit is activated when the range circuit range counter is providing a range indication from range 1 to 8.

The range counter is similar to the type used for the 1I and 2I counters. It is a reversible, four-stage 1-2-4-8 decade counter that feeds a decoder that converts to nine lines

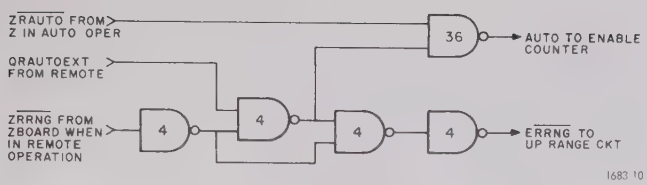


Figure 4-38. Mode circuit.

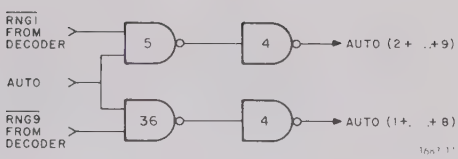


Figure 4-39. Auto-ranging circuit.

corresponding to ranges 1-9. The counter is connected in such a manner that a zero and a 10 to 15 count are not allowed. The decoder outputs are sent to the Z board for driving appropriate displays on the H board, to the data-output board (N board) for driving peripheral equipment, and to the Y board for changing the range of the bridge.

Mode Circuit. Figure 4-38 shows the mode circuit. The output of IC36, AUTO, is a "1" when the front-panel RANGE switch is set to AUTO, or when the switch is set to REMOTE and a 0-V QRAUTOEXT signal from an external source is applied to the appropriate pin connection on the AUXILIARY socket. The AUTO "1" signal enables the range counter decoders, allowing the range signals to be fed to the other circuits.

ERRNG (disengage remote hold range) is "0" if the instrument is in the remote mode and a QRAUTOEXT 0-V signal is applied externally to the instrument. The "0" disables the gates on the Q board that allow external range signals to drive the 1683 circuits and displays. This will allow the overriding of the remote operation and disengaging of any remotely produced "hold" range, since the gates on the Q board are disabled and the E board range counter is enabled by a resultant "1" AUTO signal that occurs under these conditions.

Auto-Ranging Circuit. This circuit is part of the direction-control circuit. Figure 4-39 shows the auto-ranging circuit. The AUTO signal produced by the limits circuit also enables the autoranging circuit, allowing the range circuit to range automatically. If the counter is not in range one, the output of the range-one decoder of the range counter is "1", producing a "0" that is inverted to produce the AUTO (1+ . . . . . +8) signal. If the counter is not in range nine, the output of the range-nine decoder is "1", producing a "0" that is inverted to produce the AUTO (2+ . . . . . +9) signal. These signals are applied to the up-range and down-range circuits, respectively, to command the counter to count up or down.

Up-Range—Down-Range. Figure 4-40 shows the up-range and down-range circuits. These circuits are also part of the

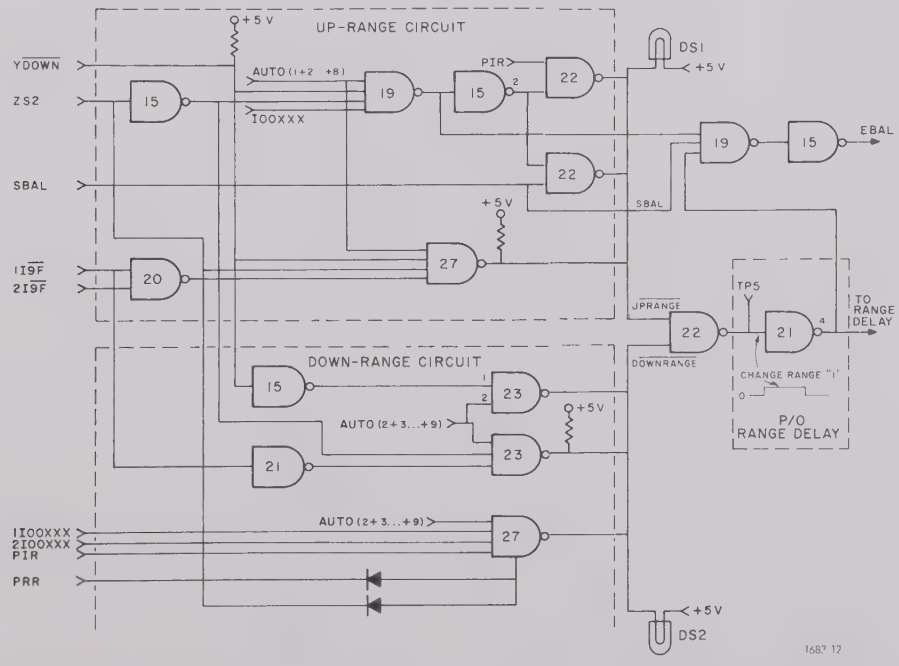


Figure 4-40. Up-range and down-range circuits.

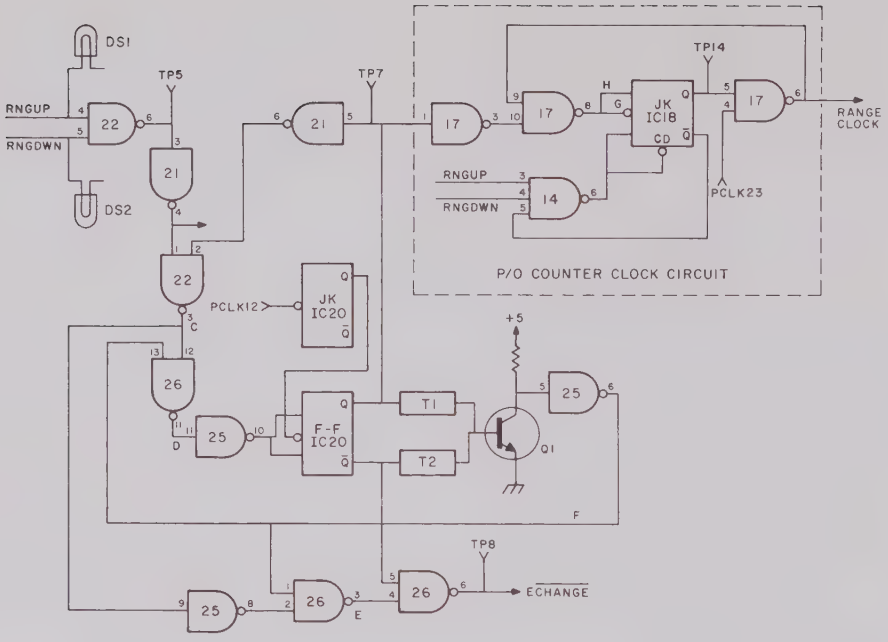


Figure 4-41. Range delay circuit.

direction control circuitry. The range circuit will be commanded to count forward when there is a 119999F (1I9$\overline{F}$) or 219999•F (2I9$\overline{F}$) signal from the counters, an auto ranging (AUTO 1-8) signal, inductance measurement being made (ZS2), and the current-to-voltage amplifier on the Y board is not saturated (Y$\overline{DOWN}$). This will produce a "1" level at TP5, indicating a change or possible change of range is required (refer to paragraph 4.4.11). Also, if there is a 100XXX•R signal, capacitance measurement being made (Z$\overline{S2}$), not Y down (Y$\overline{DOWN}$), AUTO 1-8, and a reverse capacitance count is indicated (PIR), this condition indicates the resolution for a capacitance reading is too low, and the range counter should range upward. If a balance indication (SBAL) occurs during any of these phases, a balance condition will not occur; a balance, therefore, is prevented during any ranging or possible ranging operation.

A down command will be produced by the down range circuit by a "0" Y$\overline{DOWN}$ and AUTO 2-9. Y$\overline{DOWN}$ also inhibits the up command. A down command is also produced when 1100XXX, 2100XX, inductance being measured (ZS2), and AUTO 2-9 are all present; or when 119999•F, capacitance is measured (Z$\overline{S2}$), and AUTO 2-9 are all present.

Note that a balance signal (EBAL), which is fed to the program (P) board, will not occur during any change of range or possible change of range. It will only occur when SBAL; the output of IC19, pin 6; and output of IC21, pin 4 (a "1" when no range change is indicated), are all "1". EBAL with E$\overline{CHANGE}$ sets the balance flip-flop on the P board, inhibiting certain circuits when a balance is obtained (paragraph 4.4.10).

Indicator lamps DS1 and DS2 will light when a change or possible change of range may occur; DS1 for an up-range, DS2 for a down-range change.

The U$\overline{PRANGE}$ signal is also used to enable or disenable the appropriate wired OR gates of the range counter, to allow the counter to count up or down.

Range Delay. Figure 4-41 shows a diagram of the range-delay circuit. Timing diagrams, Figures 4-42 to 4-44, illustrate three different timing conditions so that operation can be understood: (1) when a change of range is required on all ranges (TP5 is always a "1"); (2) when there is one change of range and another might be necessary – the first timing period is completed and the second period is started, and the bridge indicates that a change of range might be necessary (TP5 is a "1" during a portion of the second time period, T2); and (3) a change of range is indicated but the bridge decides not to change range (TP5 goes to "0" during time period T1).

The operation of this circuit can best be described by looking at Figure 4-41 and the timing diagrams (Figure 4-42 to 4-44) for each of the above described conditions. The circuit must look at the signal at TP5 and determine if a range change is in order. If one is, a RANGE CLOCK pulse that commands the range counter to change one count will be produced at pin 6 of IC17. Also, signal E$\overline{CHANGE}$ will be produced to inhibit the oscillator (first 5 ms) and the main gates (25 ms) during the range or possible range change and to reset the balance flip-flop on the P board to prevent any possible balance condition from occurring during this time.

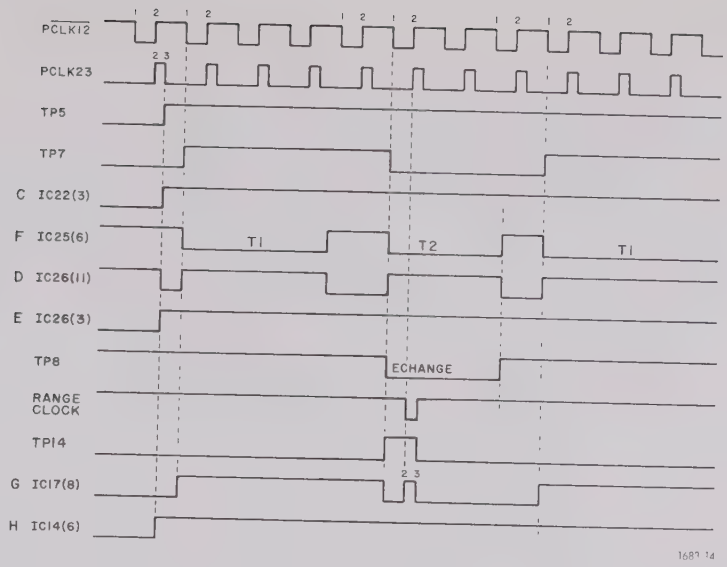


Figure 4-42. Timing diagram, change range on all ranges.

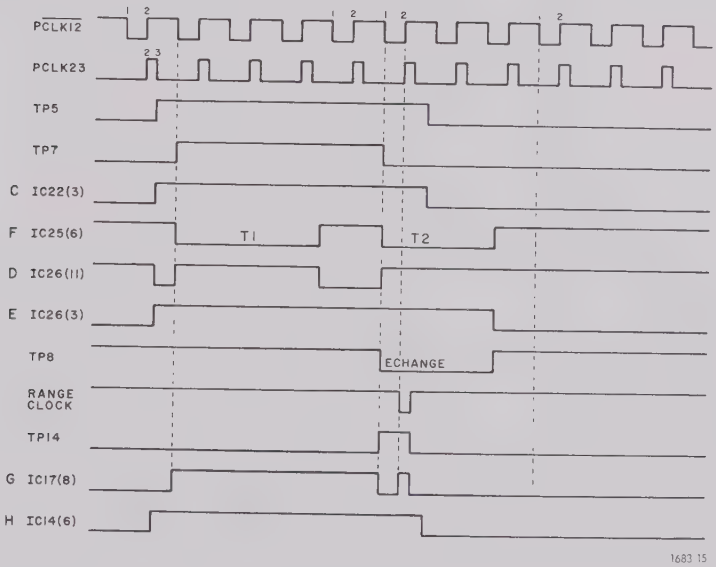


Figure 4-43. Timing diagram, change one range and possibly next range.

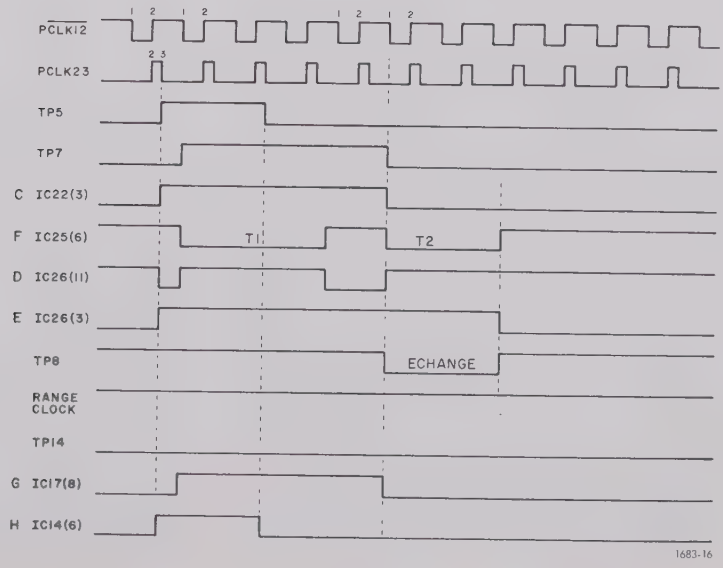


Figure 4-44. Timing diagram, start range change then stop change.

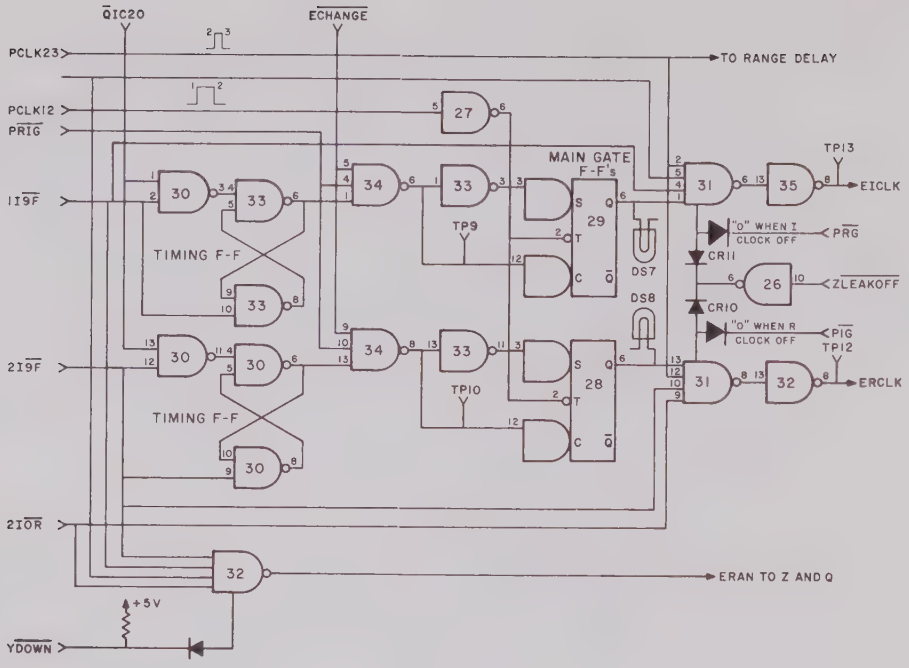


Figure 4-45. Main gates.

Essentially what happens in the delay circuit is that when TP5 goes to "1", the set and clear gates of flip-flop IC20 are enabled, since the pin-6 output of IC25 is initially a "1". The flip-flop is then set by the negative-going edge of PCLK12, causing the output of IC25(6) to go to "0" and disable the gates of the flip-flop. Note that PCLK12 is frequency-divided by JK IC20 before being applied to flip-flop IC20, and, therefore, the switching action of flip-flop IC20 is one-half that of the pulse rate of PCLK12, shown in Figures 4-42 to 4-44. (The switching of IC20 occurs on the second PLCK12 pulse.)

At the end of time T1, determined by time delay T1, the Q output of IC20 passes through the delay, turns on Q1 and produces a "1" at IC25(6), enabling the gates again. Even if TP5 did not stay a "1" for this length of time, as shown in Figure 4-44, the gates will still be enabled, since TP7 is now "1" because of the set condition of the flip-flop, which allows the flip-flop gates to be enabled by IC25(6). PCLK12 then resets the flip-flop, causing IC25(6) to go to "0". TP7 then goes to "0". After time T2, determined by time delay T2, Q1 is turned on by the $\overline{Q}$ side of IC20, causing IC25(6) to go to "1". This action produces signal $\overline{ECHANGE}$, a 25-ms "0" level.

The RANGE CLOCK signal is produced if a range-up or range-down "0" signal at gate IC14 remains "0" for the time it takes TP7 to go "0", or time T1, causing the clock input (point G, Figure 4-41) of JK flip-flop IC18 to go to "0", setting flip-flop IC18. This enables gate IC17 for pulse PCLK23, which produces the clock pulse.

Since the level at TP7 represents time T1, an up-range or down-range signal that remains at gate IC14 for this time indicates a definite change of range. $\overline{ECHANGE}$ will then inhibit the circuits described above during time T2 for the range change. $\overline{ECHANGE}$ is always produced as long as there is a possible change of range.

If TP5 remains "1" during time T2, but not for the whole time, IC20 cannot be set again, since its gates will not be enabled. Therefore, a "1" cannot be produced at TP7 to produce another RANGE CLOCK signal. However, if TP5 stays "1" for this or more T2's, the process will repeat for as many range changes required.

Flip-flop IC18 is cleared by the output IC17(6), which causes the flip-flop T input to go to "0" again, resetting the flip-flop, or when all the inputs to gate IC14 are "1".

Main Gate. The main gate produces two separate clock pulses, one for the 1I counter (EICLK) and one for the 2I(R) counter (ERCLK). Figure 4-45 shows the circuit. The clock pulses are produced by signal PCLK12, which drives the flip-flops, and the PCLK23 pulse. When the flip-flop is set to "1", and a "1" is present at all the inputs to NAND gates 31, except the PCLK23 input, the PCLK23 pulse is passed through the gates when it is applied to the NAND gates under this condition. The following signals disable the main gates:

1. $\overline{ZLEAKOFF}$ ("0" at NAND 31 when measuring leakage).
2. $\overline{PIG}$ and/or $\overline{PRG}$ (a "0" to disable the appropriate NAND 31 circuit and turn off clock).
3. $\overline{ECHANGE}$ from the delay circuit.
4. 1I$\overline{OR}$ ("0" when 1I counter is 00000 and reverse).
5. 2I$\overline{OR}$ ("0" when 2I counter is 00000 and reverse).

6. Timing flip-flop (IC's 30 and 33) outputs that synchronize the clock with the range change.
7. $\overline{\text{PRIG}}$ when the bridge is balanced and not in the track or test modes or when an external INHIBIT signal is applied to the DATA-OUTPUT connection.
8. 1I$\overline{\text{9F}}$ ("0" if 1I counter is 1999•F).
9. 2I$\overline{\text{9F}}$ ("0" if 2I counter is 19999•F).

Signal PRIG enables both clocks in the test and track modes, when the bridge is unbalanced, and if it is not externally inhibited. This signal, however, is not synchronous with PCLK23 and therefore could possibly come up during a PCLK pulse, causing a short pulse. The timing flip-flops synchronize the PRIG signal with PCLK12 before PCLK23 is allowed into the main gate. T2 ($\overline{\text{ECHANGE}}$) from the range delay is also synchronized.

The timing flip-flops disable the applicable main gate when the 1I or 2I counter reads 19999 and forward (9F). When IC20 of the time-delay circuit is reset, indicating time-delay T2, the timing flip-flop(s) is set, enabling the gate(s), if the other conditions are favorable. When 1I9F, 2I$\overline{\text{9F}}$, 2I$\overline{\text{OR}}$, 1I$\overline{\text{OR}}$ or YDOWN is a "0", signal ERAN is produced and forwarded to the Z board to light the RANGE indicator, indicating a change of range may be required.

Range Counter Clock. Figure 4-41 shows the range counter clock circuit. Normally, JK flip-flop IC18 is reset, Q being a "0". Gate IC17(6) is then disabled, its output a "1". This output is fed to IC17(9) as an enabling level. When a RNGUP or RNGDWN signal goes to "0", indicating a range change may be necessary, the JK flip-flop inputs are enabled by the resultant "1" at IC14(6). Since a change of range has been indicated, TP7 on the range delay will have gone to "1", This produces a "1" at point G, the flip-flop clock input. When TP7 goes to "0" at the end of time T1 (6 ms), the flip-flop will be set if signal RNGUP or RNGDWN is still "0". When set, gate IC17(6) is enabled and PCLK23 is gated through when applied to the gate. Since IC17(10) is now a "1", the flip-flop will be reset when IC17(6) goes back to "1" after PCLK23 is gated through it. The $\overline{\text{Q}}$ output to IC14(5) ensures that the flip-flop is reset in case the range control signals go to "1" before the reset action occurs.

Counter and Decoder. These circuits are described previously in this paragraph. Note that indicator lamps DS3 through DS6 on the board light to indicate a BCD count (1-4-2-8) and will light appropriately for any given 1 to 9 count. The counter is somewhat similar to the 1I and 2I counters, the forward and reverse action being produced in the same manner. The counter is also a 4-stage counter, with counts of 10-15 prohibited. This counter, however, prohibits a zero count.

4.4.12 Counter Circuits (Figures 6-11 and 6-12).

The two counter circuits (I boards) are designated the 1I counter and the 2I counter. The 1I (I) counter is associated with the measurement of inductance and capacitance, the 2I (R) counter with resistance and dissipation-factor measurements. Both counters are identical; therefore, only the 1I counter will be described.

Figure 6-11 is a block diagram of the 1I counter and associated displays. The counter consists of four, 4-stage 1-2-4-8 BCD decades and one flip-flop. The decades arranged to count 0 to 9 and are cascaded to count "units", "tens", "hundreds", etc. The flip-flop, referred to as the "spillover" flip-flop, counts 1 when the four decades exceed a 9999 count, thus indicating a "ten-of-thousands" count. The counter is a reversible counter, counting forward as well as reverse. For example, when the decades are reset to zero, the first decade ("units") will count up to nine and enable the next decade. The next clock pulse (CLK) will then set the next decade to a one count and the "units" decade to zero. The "units" decade will again count to nine and the "tens" decade will be set to a two count, and the "units" decade to zero on the twentieth clock pulse. This is repeated until the four decades and flip-flop count 19999.

If the counter counts reverse, a decade preceding another decade provides an enabling signal to that decade when it (the preceding decade) reaches a count of zero. The next clock pulse then causes both decades to count down one count (the first decade counts a nine). Clock-type flip-flops are used in the counters.

The operation of the counter depends on the clock signal and the Reverse (R) and Forward (F) signals. The clock signal is produced on the reference board (S board) and passed through the main gates on the range board (E), which generate two separate clock pulses — one for the 1I counter and one for the 2I counter. The clock pulse rate is determined by the magnitude of the error signals, DE.

A fast clock rate is produced for a large error, and a progressively slower clock rate is produced for a smaller error. The clock signal can be gated on or off on the E board by certain conditions described further on in this paragraph. Refer to paragraphs 4.4.9, 4.4.10 and 4.4.11 for a description of the clock signals.

The F and R (PRR) signals determine the direction the bridge should balance, i.e., the direction the counters should count — forward or reverse. These signals are produced on the P board by the phase-detector flip-flops. When the bridge is balanced, the same circuitry on the P board produces a "stop" signal that inhibits the clock signal-gate on the E board, which stops the counters from counting. The reverse signal (PIR or PRR) is a logical "1" that causes the counter to count in reverse. The reverse signal is the inverse of the forward signal (F), as shown in Figure 6-11.

The output of the counters is fed to inverter-drivers and decoders on the display board. The inverted outputs of each decade are applied to a single decoder which decodes the count (0 to 9) of the decade and provides outputs to

the numerical readout tube and indicators on the front-panel display.

The $\overline{Q}$ output of each flip-flop in the counter circuit is fed to the appropriate divider board and to the data-output board (N board) and socket for driving peripheral equipment. At the divider board, the signals are applied to a ladder network that adjusts the divider in such a way as to minimize the error signal. The counters are then operating and adjusting the precision dividers and will continue to count until a balance is reached or there is overshoot, at which point the counters will reverse direction and count until a balance is finally achieved. The counters (or actually the displays) will then read the value required to adjust the divider and reduce the error signal to zero and, therefore, the value of the part under test.

The outputs of the counters are also applied to three NAND gates, two of which are extended NAND gates. The Q side of flip-flops 1 and 4 (9 count) in each decade and the spill flip-flop are ANDED to provide a "0" output when a count of 19999 forward (F) exists; this is the $\overline{9F}$ signal. When a count of 00XXX, or only a "hundreds" count exists, the $\overline{Q}$ outputs of the spillover flip-flop and flip-flops of the "thousands" decade counter are ANDED to provide a "0" output (00 signal). When all the flip-flops indicate a 00000 count, the $\overline{Q}$ logical "1" outputs of all the flip-flops are ANDED to provide a "0" ($\overline{OR}$) that indicates all the decades read zero. These signals are fed to the E board for detecting a change in range and inhibiting the main gates. Signals $\overline{OR}$ and $\overline{9F}$ will also be used for lighting the front-panel RANGE indicator, indicating a RANGE change may be necessary. Signals 00 and $\overline{9F}$ are used by the up-range and down-range circuits for detecting the range change. The $\overline{OR}$ signals (1I and 2I) disable the appropriate gate of the main gates on the E board that gates the clock (CLK) pulses to the counters. The counters continue counting until a balance is reached; range changes occur as necessary.

All the decades can be set to a zero count by pressing the front-panel SET ZERO pushbutton switch. This produces signal ZSETO that resets the decades.

4.4.13 Auxiliary Board (Figure 6-20).

The Auxiliary (data-input) board (Q board), an available accessory, acts as a buffer for input and output programmable signals between the 1683 circuits and peripheral equipment; these buffered signals are those used for programmable operation of all control functions of the 1683 except line-voltage control. Most of the signals are compatable with diode transistor logic (DTL) and transistor-transistor logic (TTL or T^2L) or can be controlled by switch closures to ground. Therefore, the input signals can be standard DTL or TTL signals with non-critical rise and fall times. Signals LEAKOUT and LEAKAGE are analog signals. YGL is used with LEAKOUT and SENS. SENS is a programmable resistance tied between the SENS input (Q board) and YGL, to externally establish the sensitivity of the instrument, if desired. Timing of the signals is not critical and only the pulse width of the $\overline{QSING1}$ is critical; the width must be greater than 0.5 μs and less than 50 ms. (The input START signal on the N board is the only other signal that has a critical pulse-width requirement; this must be greater than 20 μs.)

Filters on all of the input lines provide noise suppression. IC gates for input signals are activated when the front-panel mode switch is set to REMOTE, gating the signals to applicable circuits. Most of the input signals are routed through the front-panel control board (Z board), where they are gated or switched to applicable lines. Output signals are received via the mother board (M board) and after inversion are fed directly through the socket on the board to external equipment. Table 4-11 lists the input signals, their function, and routing.

Externally applied signals should be approximately zero volts, or a switch closure to ground, with a 10-mA sink capability. Table 4-12 lists the output signals from the Q board to external equipment, describes the functions they perform, and identifies the origin of the signal.

4.4.14 Data-Output Board (Figure 6-17).

The data-output board (N board), an available accessory, provides a buffer between the 1683 circuits that drive the front-panel indicators and external recording or similar type equipment (data printers, card punches, etc.), for recording data. Two types of boards are available; one for a low-level data output, and one for a high-level data output. The low-level board provides 11 digits of measurement data (5 for resistance, 5 for reactance, 1 for range) plus various control inputs and outputs for system use. Digits are 1-2-4-8 weighted BCD at standard TTL logic levels (logical "0" $\approx$ ground with a 10-mA sink capability; logical "1" $\geqslant$ 3.5 V).

The high-level data output is the same as the low-level, except all outputs are of a 15-V swing (logical "0" $\approx$ ground with a 10-mA sink capability; logical "1" $\approx$ 15 V behind 12 kΩ).

The 1683 can be started with a direct-coupled or ac-coupled START signal input to this board. This signal can be a maximum of ± 50 V. The ac-coupled signal must be greater than 8 V, peak. Both types of signals must be present for a minimum of 20 μs. The dc- or ac-coupled signals can be connected on the board to trigger a start pulse ($\overline{NSING2}$) on the positive- or negative-going transition of the START pulse. The dc-coupled signal can be connected to trigger the pulse a +5-V, -5-V, or +1.5-V level. Instructions for making the applicable connections are given on the board schematic. Wires are provided on the board for the connections and may be soldered if desired.

The IC inverters enclosed in dotted lines on the schematic are plug-ins and can be removed and replaced for interchanging the logic levels described above.

Table 4-11
Q-BOARD INPUTS

Signal	Routing	Function
SING1	Directly to P board.	Electronic pulse that starts a balance or leakage operation. Pulse width must be greater than 0.5 μs, but less than 50 ms.
STOP	Via Z board. Connects to PRIG signal output (pin 16) on P board.	Inhibits main gates on E board, turning off counter clocks for any mode of operation.
INHIBIT	Directly to P board as $\overline{\text{QINH}}$.	Allows peripheral equipment to inhibit start of operation by inhibiting signal QSING1 derived from an external source, and as signal $\overline{\text{QINH}}$, inhibits start operation by PVMR generator on the P board.
CLRDATAFF		Clears F-F IC14, if set, to indicate the bridge is busy performing an operation.
DONE	From P board.	Signal produced by "Balance" F-F (IC26) and "start" F-F on P board to indicate to external equipment that the bridge is busy with an operation. When signal goes to "1", indicates the bridge is balanced and awaits a command.
TRACK	Via Z board to P board.	At P board, produces signal $\overline{\text{PRIG}}$ that holds main gates on E board open so that counter clocks will run continually (usually for measurements).
VAR	Via Z board to P board.	Allows the rate of variable measurement rate generator, and, therefore, the rate of a balance or leakage-current measurement, to be manually regulated with the front-panel VARIABLE MEAS RATE control.
$\overline{\text{BIAS}}$	To J board	Disables the power amplifier (J board) bias input when it is desired to change or vary the bias.
RNG1-RNG9	Via Z board to Z board matrix and Y board.	At Z-board matrix, produces signals to drive indicators on display board. At Y board, adjusts the Y-bridge current divider connected to the low-current terminal, to establish the range of the instrument. Table 3-1 lists the ranges.
RAUTOEXT	Directly to E board.	When the instrument is in the remote mode, signal will override the remote mode and activate the 1683 range counter for automatic operation. Signal will also disable the gates on the Q board that gate in external range (RNG1-RNG9) signals.
1000	To Z board. As ZS3 to Z board matrix and C, D, M, S, and T boards. As ZL1 and ZL10 to H and U boards. As $\overline{\text{ZS3}}$ to Z-board matrix. As $\overline{\text{ZS3D}}$ to D board.	Allows measurements at 1 kHz. ZS3 switches in paths, components, or filters for a 1-kHz signal and activates the Z-board function-display gates for 120-Hz measurements. ZL1 activates U-module 120-Hz lamp and ZL0 activates U-module 1-kHz lamp. $\overline{\text{ZS3D}}$ switches in components in the anticipator circuit on D board.

Table 4-11 (Cont)
Q-BOARD INPUTS

Signal	Routing	Function
LR	To Z board. As ZS2 to Z-board matrix and E, J, K, M, and P boards.	Allows measurement of inductance or series resistance. $\overline{ZS2}$ disables C-function range-display gates on Z board. ZS2 enables L-function range-display gates on Z board, switches in bridge divider and inductance standard on K and M boards, and indicates to E, P, and J boards that inductance is being measured.
CD	To Z board. As ZS1 to Z-board matrix and B divider. As ZS2 to D front-panel display and P board.	Allows measurement of capacitance with D as a loss. ZS1 enables function- and range-display gates on Z board and switches in the positive input to B-divider output operational amplifier (positive gain for D).
CR	To Z board. As ZS4 to relays on B and C dividers.	Allows measurement of capacitance with equivalent series resistance (ESR). ZS4 switches C divider into bridge, switches out the YC path and switches in the output of the C divider (CC path) to the B divider.
LEAKOFF	To Z and P boards.	A "0" inhibits a leakage-current measurement by disabling F-F IC28 on P board, so that alternate start pulses will not produce a leakage measurements (if leakage and capacitance are being measured).
LEAK2-LEAK5 (LEAK1 is not used)	Via Z board to L board.	Establishes five ranges in which the current can be measured, by switching in appropriate feedback networks on the L board input amplifier. Table 3-2 lists the magnitude of the ranges for each signal.
SENS	Via Z board to S board.	Programmable external resistor (R_{ext}) tied between SENS and YGL that loads the SENS output (1 kΩ) on the S board, establishing externally the instrument's sensitivity level; i.e., count error to one count or less, 8 counts or less, etc. Refer to paragraph 3.11 for details.
YGL		Ground reference that must be used when measuring LEAKOUT or using SENS input.
SET 0	Via Z board to I and R counter boards.	Sets counters and displays to zero whenever it is desired to do so.
REMSET		For external leakage-current measurements (para. 3.19). A momentary "0" applied after the time allowed for the leakage measurement produces a "go" indication (REMGO) for an acceptable leakage current.
LEAKAGE	Via Z board to L board.	Leakage reference signal in lieu of front-panel-controlled leakage-reference signal. Zero to 25 V, corresponding to the ratio: leakage current = V/10, for selected range.
SIGOFF	Q board as QOSCOFF	Disables oscillator for performing leakage measurements only.

Table 4-12
Q-BOARD OUTPUTS

Signal	From	Function
$\overline{\text{DONE}}$		Derived from signal PBUSY. Indicates instrument is performing a balance or leakage-current operation. Signal goes to "1" when operation is completed.
PRR	P board	Commands resistance counter (2I) to count reverse ("0" reverse, "1" forward).
PIR	P board	Commands reactance counter (2I) to count reverse ("0" reverse, "1" forward).
BAL	E board	"0" indicates bridge is balanced.
UNBAL	S board	"0" indicates bridge is unbalanced, (error is more than 8 counts.)
NG	L board	When signal output goes to "1", indicates leakage-current within established limit.
LEAKOUT	L board	Analog signal from 0 to −2.5 V proportional to the leakage current in the measurement range; e.g., 2.5 V equals 2.5 μA, 25 μA, 250 μA, etc. (Refer to Table 3-2.)
ABORT	P board	Indicates unbalanced condition has exceeded 2.5 s, the maximum time allowed for a balance.
RAN	E board	A "1" indicates a change of range is not necessary; a "0" indicates a change may be necessary.
+15 V, −15 V, +5 V	System bias voltages	Reference signals only; not more than 50 mA must be drawn when used for reference.
REMGO	L Board	Used for external leakage-current measurements (para. 3.19). Goes from "1" to "0" after momentary "0" REMSET is applied to pin 47, if an acceptable leakage-current condition exists.
GND(YG)	Ground reference.	

Table 4-13 lists the signals, origin of the signals, and function of the signals handled by the N board.

4.4.15 Display Board (Figures 6-9 and 6-10).

General. This display board (H board) presents all the visual information to the operator. The value of the measured unknown is shown by numerical readout tubes (V1 to V10). These tubes are driven by four-to-ten line decoder-drivers (IC's 2-5 and 7-10) that convert the 1-2-4-8 code from the 1I and 2I counter decades to 10-line decimal data. IC's 1, 6 and 11-14 act as buffers between the converter-drivers and the counters.

Range signals from the Z board switch in transistors Q1-Q4 and Q7-Q9 to illuminate the appropriate decimal point of a readout tube. The readout tubes are plug-ins and are replaceable.

There are three modules containing indicator lamps that plug on to the H board. These are designated the F, G, and U modules.

F. Module. This module contains the GO, NO GO, D, KΩ, Ω, and MΩ, lamps. These are driven by appropriate

Table 4-13
N-BOARD SIGNALS

Signal	Origin	Function
COLOR	P-board balance flip-flop and delay circuit (signal PABORT)	Indicates a balance operation has exceeded 2.5 s, the maximum time allowed. Signal is useful for producing a printout in a different color, indicating an unsatisfactory balance.
BUSY	P-board balance flip-flop.	Produces a print-data command when a balance is completed.
INHIBIT	External equipment	Produces signal $\overline{\text{PRIG}}$ that inhibits the main gates on E board and hence the displays.
START	External	Starts balance operation. Details of signal are given at the beginning of this paragraph. Signal INHIBIT must be removed before a START signal is applied.
NI0-NI16	1I board (I)	BCD outputs of counter decades to drive five digits. NI16-13 is first digit, NI12-9 is second digit, etc. NI0 is tens-of-thousands digit (spillover).
NR0-NR16	2I board (R)	Same as above except for 2I board (R data).
RNG 1, 2, 4, 8	E-board range counter	Establishes measurement range. Refer to Table 3-1 for ranges. Signals are in BCD weighting of 1-2-4-8.
NVREF		Logical "1" voltage reference. Not more than 50 mA must be drawn when used for reference.
GND		Ground references.

signals from the control (Z) board. The functions of these and the lamps in the other modules are described in paragraph 1-3. The module and the G and U modules also contain spare lamps for the symbols in case a lamp burns out.

G Module. This module contains the RANGE, UNBALANCED, H, mH, μH, nH, mF, μF, nF, and pF lamps. These lamps are also driven by signals from the Z board.

The RANGE and UNBALANCED lamps each consist of two bulbs.

U Module. This module contains frequency indicator lamps 120 Hz and 1 kHz. Each of these lamps consist of two bulbs.

4.4.16 Power Supply and Transformer (Figure 6-25).

The power supply provides a regulated −15 V, +15 V, +10 V, and +5 V for circuit operation. The regulator circuits are on the power supply board (V board). The line-transformer secondary and associated rectifiers supply +21.5, −21.5, and +8 V to the regulator circuits on the board; +8 V and −8 V to the amplifier board (J); +250 V to the H board numerical readout-tubes; and signal ASYNC, a1−Vac signal that synchronizes the oscillator with the line frequency, to eliminate any "beating" effect.

The bias voltages are regulated by feedback circuits to amplifiers. The −15−V supply has a "starter" circuit (R16, R18, and CR4) with an output, 'A', that starts up the +15 V supply.

Both the −15 V and +15 V supplies have adjustments that may, on occassion, require adjustment. Since the −15 V supply starts the +15 V and the +15 V supply biases the +10 V and +5 V supplies, the −15 V supply must be adjusted first.

A circuit breaker, A-CB1, in the input line protects the IC's by shutting down the bridge if the +5 V bias voltage becomes excessive. A line selector switch on the rear of the instrument allows selection of line voltages of 100-125 V or 200-250 V. A 1.25-A Slo-Blo fuse is provided for the 100-125 V, and a 0.6-A fast acting fuse for the 200-250 V. When the instrument is turned on, a blower, A-B1, circulates cooling air through the instrument.

4.4.17 Control Board (Figures 6-27 and 6-28).

The control board (Z board) contains the controls and circuitry that activate and control the functions of the bridge, and contains decoders that decode the count of bridge range counter to drive the decimal points and component symbols on the display board (H). The decoder outputs are fed to gates associated with H. F, and Ω quantities and dissipation factor. The applicable gates are enabled by the position of the function selector and by the selected 120-Hz or 1-kHz measurement (signals $\overline{ZS3}$ and ZS3, respectively). Signals that light front-panel indicators (LNG, LGO, ERAN, and SUNBAL) are also routed through the Z board to the display board. Signal PRIG, which controls the main gates on the range board (E), is also routed through the board to inhibit counting during switching.

Programmable control signals that can control the 1683 in lieu of front-panel controls are routed from the Q board (when used in the instrument) when the front-panel controls are set to REMOTE. In this position the controls enable input gates on the Q board, allowing signals to enter the 1683. Also, in this position, the controls allow outputs from the instrument that are necessary for programmable operation. The Q board schematic shows the signals. Paragraph 4.4.13 describes the signals and their function. These signals include the range, leakage range and control, mode, start, measurement condition (LNG, ERAN, UNBAL) shown on the Z board, in addition to signals routed directly to the Q board.

Circuitry on the schematic is self-explanatory. Paragraph 1-3 contains a description of the controls and their function.

Service and Maintenance—Section 5

5.1 GR FIELD SERVICE 5-1
5.2 INSTRUMENT RETURN 5-1
5.3 REPAIR OF PLUG-IN BOARDS 5-1
5.4 MINIMUM PERFORMANCE STANDARDS 5-1
5.5 PARTS LOCATIONS 5-4
5.6 REMOVAL-REPLACEMENT 5-8
5.7 REFERENCE DESIGNATIONS 5-8
5.8 TEST POINTS 5-8
5.9 CIRCUIT BOARDS INDICATOR LAMPS 5-8
5.10 PERIODIC MAINTENANCE 5-14
5.11 CHECKS AND ADJUSTMENTS 5-14
5.12 TROUBLE ANALYSIS 5-21
5.13 SERVICING ETCHED-CIRCUIT BOARDS 5-21

5.1 GR FIELD SERVICE.

The two-year warranty attests the quality of materials and workmanship in our products. When difficulties do occur, our service engineers will assist in any way possible. If the difficulty cannot be eliminated by use of the following service instructions, please write or phone our Service Department (see last page of manual), giving full information of the trouble and of steps taken to remedy it. Be sure to mention the serial, ID, and type numbers of the instrument.

5.2 INSTRUMENT RETURN.

Before returning an instrument to General Radio for service, please contact our Service Department or nearest District Office requesting a "Returned Material" number. Use of this number will ensure proper handling and identification. For instruments not covered by the warranty, a purchase order should be forwarded to avoid unnecessary delay.

5.3 REPAIR OF PLUG-IN BOARDS.

For prompt replacement of etched-circuit board(s), a replacement can be ordered, and the faulty board returned after receipt of the replacement. Contact your nearest General Radio Repair Facility (see last page), supplying them the type, serial number and identification number of the instrument; the board part number (refer to the parts list for the number; the number etched on the foil-only-solid-side is ***not*** the part number) and letter designation (if any); and a purchase order number. The P.O. number allows for billing if the unit is out of warranty and/or for identification of the shipment. The repair facility will arrange for the prompt delivery of a replacement.

To prevent damage to the board, return the defective board in the packing, or equivalent packing, supplied with the replacement. Please identify the return with the Return Material number on the tag supplied with the replacement and ship to the address indicated on the tag.

5.4 MINIMUM-PERFORMANCE STANDARDS.

5.4.1 General.

The following paragraphs contain information to determine that the 1683 is performing within specifications. The procedures enable instrument-standards laboratories and equivalently equipped service facilities to perform checks at periodic intervals and after repair, to determine that the instrument is operating properly. These procedures are bench checks that require the use of front-panel controls and externally available test points (i.e., instrument disassembly is neither required or recommended).

Table 5-1 lists the recommended test equipment for a minimum performance check, adjustment and calibration procedures, and trouble analysis.

The following checks are included, to determine that the instrument is operating properly:

1. Measurement accuracy
2. Counter check
3. Ranging check
4. Leakage-current function
5. Oscillator-level check
6. Remote-operation check.

Table 5-1
TEST EQUIPMENT

Instrument	Requirement	Recommended*
Oscilloscope	5 m V/cm sensitivity, 10-MHz bandwidth, 35-ns rise time, dual trace.	Tektronix type 535
Oscilloscope plug-in		Tektronix Type 1A1
Dc voltmeter	Range 5 – 15 V with 1% of reading accuracy; 250 V with 5% accuracy; impedance greater than 100 kΩ	General Radio Type 1807 Dc Microvoltmeter/Nanoammeter
Ac voltmeter	120- and 1-kHz frequencies; range 0-5 V, 100 kΩ impedance; accuracy ±2% of reading	General Radio Type 1806 Electronic Voltmeter
Electronic counter	Range 120 Hz – 1 kHz, sensitivity 1 V rms, impedance 100 kΩ; five-digit readout	General Radio Type 1192 Counter
Precision capacitors	1000 pF 100 pF 10,000 pF .01 μF 0.1 μF 1.0 μF	GR Type 1404-A GR Type 1404-B GR Type 1615-P1 GR Type 1409-L GR Type 1409-T GR Type 1409-Y
Precision decade capacitor	100 pF – 1.005 μF in 100-pF steps. .05% accuracy	GR Type 1423 Precision Decade Capacitor
	1 – 10 μF in 1–μF steps	GR Type 1424-A Decade Capacitor
	10 μF – 100 μF in 10-μF steps	GR Type 1425 Decade Capacitor
	10 μF – 0.1 F for measurements at 10 μF, 100 μF, 1000 μF, .01 F and 0.1 F at 120 Hz	GR Type 1426 Capacitance Standard
Precision resistor	1 Ω – 10 kΩ in 1-Ω steps, .02% accuracy	GR Type 1433-J Decade Resistor
	1 kΩ – 10 MΩ in 10-kΩ steps (for leakage-current measurement only)	GR Type 1434-P Decade Resistor
	1, 10, 100, 1 k, 10 k, 100 k, and 1 MΩ; accuracy .01%; .01 Ω and 1 Ω (other special valves available)	GR Type 1440
Standard inductors	10 H, 1 H, 100 mH, 20 mH, and 100 μH	GR Type 1482 Standard Inductors
	1 μH, 10 μH and 100 H	Suitable precision inductors
Extender boards	———	Refer to Table 1-3.

*Or equivalent

Table 5-2
COUNTER CHECK

Step	Mode Switch Position	Display	Indication
1	Press SET ZERO switch		
2	TEST 1	Reactance	Counts from 00000 to 19999
3	TEST 2	Reactance	Counts from 19999 down to 00000
4	TEST 3	Resistance	Counts from 00000 to 19999
5	TEST 4	Resistance	Counts from 19999 down to 00000

5.4.2 Measurement Accuracy.

Perform the operational check in paragraph 3.13. This check is for all functions (CsD, CsRs, and LsRs, at both measurement frequencies) except leakage current, and verifies the measurement accuracy at each range for these functions.

5.4.3 Counter Check.

Although this check is not for verifying any instrument specifications, it is a preliminary check that can be performed before checking the ranging capabilities. To ensure that the numerical displays operate properly:

a. Set the function switch to either LsRs, CsD, CsRs or REMOTE and press the SET ZERO push-button switch; all the displays should read zero.

b. Set the mode control to the positions listed in Table 5-2 and observe the indications as listed. The FAST-SLOW control can be used to vary the speed of the count.

5.4.4 Ranging.

NOTE

The range limits are defined in Table 3-1.

To ensure that the counters, displays and ranging circuits operate properly:

a. Set the function control to LsRs 1 kHz, RANGE control to AUTO, and mode control to SINGLE MEAS.

b. Connect the + CURRENT terminal to the +POTENTIAL terminal and the –CURRENT terminal to the –POTENTIAL terminal, using clip leads or coaxial cables.

c. Set the mode switch to TEST 1; the reactance display should count to a maximum reading of 199.99 H.

d. Set the mode switch to TEST 2 and count the reactance display to 010.00 H or slightly greater than this reading.

e. Set the mode switch to TEST 4 and count the resistance display down to less than 0100.0 kΩ.

f. Set the mode switch to TEST 2 and count down at a slow rate (use the FAST-SLOW-STOP control). At every second count below 01000, the reactance display should change range. For example, starting at 01000 the range should change after 00998 after 00996, etc., until the lowest range of 1999.9 nH is reached.

g. Set the mode switch to TEST 1 and count the reactance display up to 1.9999 nH, after which the bridge should up-range until the upper range of 199.99 H is reached.

h. Set the mode switch to TEST 4 and count the resistance display down to slightly greater than or to 01001; set the mode switch to TEST 2 and count the reactance display down less than 010.00 H.

i. Set the mode switch back to TEST 4 and count the resistance display down slowly to less than 01001 and observe that the range down-ranges at every second count until the lowest range of 19.999 mΩ is reached.

j. Set the mode switch to TEST 3 and count the resistance display up to 19.999 mΩ, after which the bridge should up-range until the upper range of 1999.9 kΩ is reached.

k. Set the FAST-SLOW-STOP control to STOP.

l. Set the function switch to CsD 1 kHz.

m. Using the mode switch TEST positions and FAST-SLOW control, set the reactance display to less than 199.99 pF; the D display can be at any reading.

Table 5-3

LEAKAGE-CURRENT CHECK

Leakage-Current Range	Applied Voltage	Series Resistance (Ω)	Current
1 μA	1	10 M	0.1 μA
1 μA	1	1 M	1.0 μA
1 μA	2.5	1 M	2.5 μA
10 μA	1	1 M	1,0 μA
10 μA	1	100 k	10 μA
10 μA	2.5	100 k	25 μA
100 μ	1	100 k	10 μA
100 μA	10	100 k	100 μA
100 μA	25	100 k	250 μA
1 mA	10	100 k	100 μA
1 mA	10	10 k	1 mA
1 mA	25	10 k	2.5 mA
10 mA	10	10 k	1 mA
10 mA	10	1 k	10 mA
10 mA	25	1 k	25 mA

n. Using the TEST 1 switch position, count the reactance display up to 199.99 pF. Continue to count up slowly and observe that the range changes range (down-ranges) until range 19.999 mF is reached.

o. Set the mode switch to TEST 2 and count the reactance display to read 01.000 mF, after which the bridge should up-range until range 199.99 pF is reached.

NOTE

The operation of remote programming of the functions, if included, can be verified by grounding the appropriate function pin-connection on the auxiliary board socket. (See Section 2.)

5.4.5 Leakage-Current Check.

To check the leakage-current function, if included in the instrument:

a. Apply the currents listed in Table 5-3 to the –CURRENT measurement terminal by connecting the resistors listed, in series with a variable power supply source that supplies the voltages listed in Table 5-3 and the –CURRENT terminal. A GR Type 1434-P Decade Resistor is recommended. The internal 3-V bias supply can be used for the lower voltages, by connection of the appropriate resistance between the + and –CURRENT terminals. This voltage will have to be monitored with a voltmeter to obtain an accurate setting.

b. At each current listed, set the LEAKAGE variable control to slightly more than the measured current.

c. Set the function switch to CsRs or CsD and turn on the instrument; set the VARIABLE MEAS. control for a slow measurement rate and observe that the GO indicator lights. Refer to the calibration procedure in paragraph 5.11.8, if the proper operation is not observed.

d. Set the LEAKAGE variable control to slightly less than the measured current and repeat a measurement. Observe that the NO GO indicator remains lit.

This check can also be performed by measuring capacitors whose leakage-current is known, according to the leakage-current operating procedure in Section 3.

5.4.6 Oscillator-Level Check.

If it is desired to check the oscillator level, connect an oscilloscope or voltmeter to the +CURRENT terminal and set the OSC LEVEL control to 2.2; the voltage should be 2.2 V, open circuit.

5.4.7 Remote Programming and Data Outputs.

If the instrument contains these features, they can be checked by referring to the information contained in paragraphs 2.4 and 3.11. Information for checking appropriate functions is contained in these paragraphs.

5.5 PART LOCATIONS.

Most of the parts and internal adjustments are on the etched-circuit boards. Figures 5-1 through 5-5 identify the locations of these adjustments and parts. Also shown are the adjustments on the mother (M) board for the capacitive standards.

Parts associated with the line-voltage rectifier are on the transformer shield assembly, under its top cover.

Some transistors and parts associated with the power supply (V board) are on the transistor assembly at the rear of the instrument. Paragraph 5.7 describes the reference designations used to identify chassis and circuit-board parts.

5.6 REMOVAL-REPLACEMENT PROCEDURES.

5.6.1 General.

Turn off the power before removing or installing any parts.

WARNING

When the instrument is energized, there is 250 V present at the top of A-C54 (Figure 5-1), at the transformer shield assembly, under the assembly cover, and at anchor terminal AT1 on the H board (Figure 5-1). This voltage is fed to the numerical readout tubes by means of etched lines under the H board. Be careful when the unit is energized and the chassis is out of the cabinet.

5.6.2 Chassis.

Refer to paragraph 2.5 or 2.6 for instructions on how to remove and install the chassis in the cabinet.

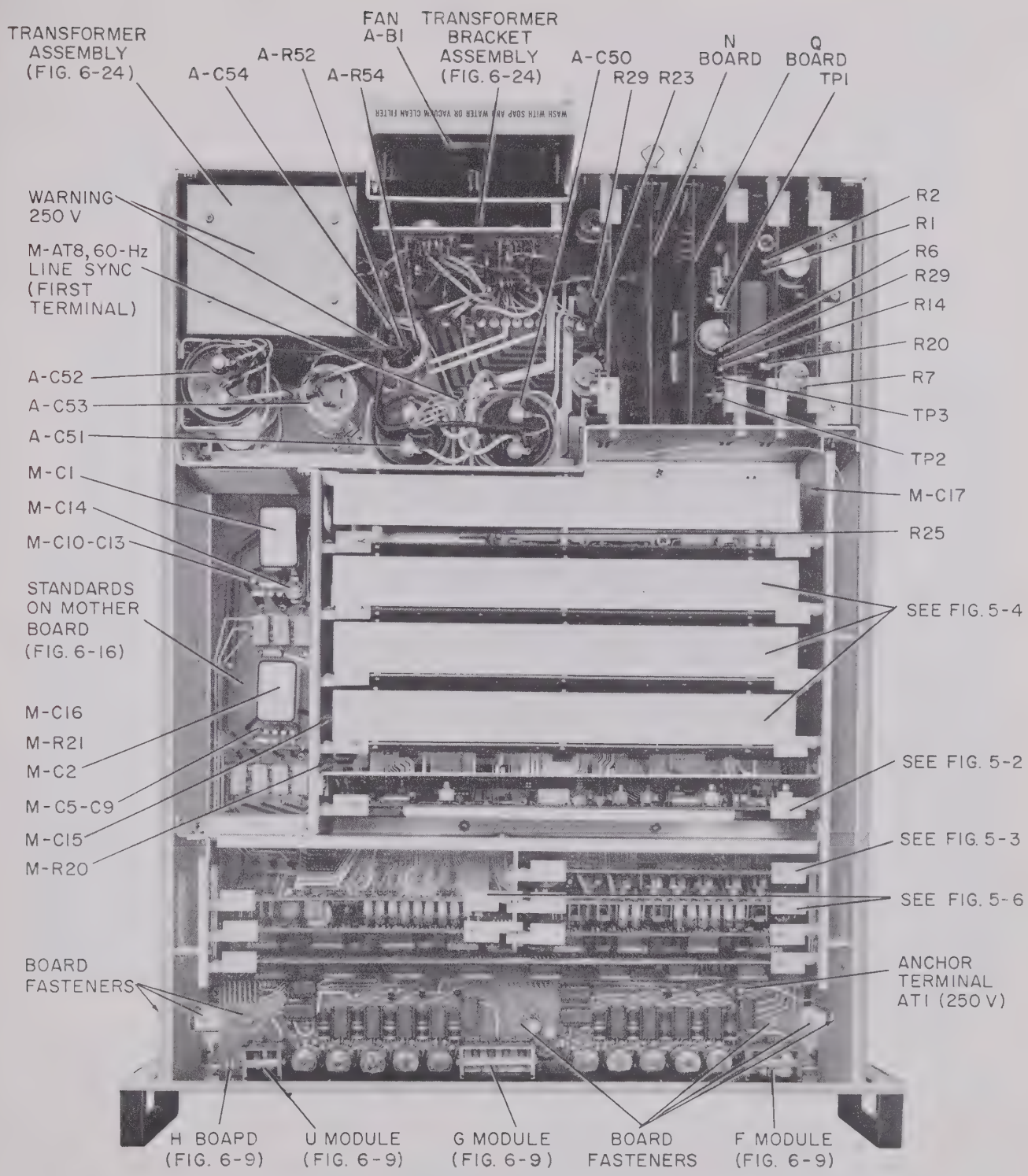


Figure 5-1. Top interior view identifying parts, adjustments, and terminals.

CAUTION

Make sure no foreign matter, especially metal, falls on the mother board when the chassis is out of the cabinet. This may short circuit mother board signal lines. Always check that the board is clean before reinstalling the chassis in the cabinet. Also, take care not to bend the socket terminal-pins on the bottom of the mother board. Bent pins could cause a short circuit or malfunction.

5.6.3 Circuit Boards.

Lift up the latches at the ends of the board and carefully pull the board from its socket. To remove the control (Z) or display (H) boards:

a. Carefully disconnect (pull up) the 250-V wire attached to H-board anchor terminal AT1 (Figure 5-1) and touch it to ground to remove any possible charge on capacitor A-C54 at the rear of the chassis.

b. Loosen but do not remove the set screw on each bracket (plastic arm) at the sides of the board. Loosen about ¼ in. the screws on the sides of the chassis that hold the bracket in place (do not remove the screws yet).

c. Move the bracket back about ¼ in. and tighten the set screw; remove the screws at the sides of the chassis.

d. Pull up the Z-board latches and carefully pull up the Z board. The H board will remove with the Z board. Make sure the control knobs clear the display windows.

e. Remove the three screws on the H board (one at each end and one at the middle).

f. Pull or pry with a piece of wood or similar object the H board from the Z board at the green connectors.

Reverse these procedures to reinstall the boards. The component side of the intermediate-sized boards at the front of the instrument face the front. The component side of the large boards face the rear and the component side of the small boards at the rear face to the left. Refer to Figure 5-1. ***Make sure the boards are seated properly and securely in the sockets.***

NOTE

If any difficulty is encountered when replacing the Z board, remove the I boards to allow clearance.

5.6.4 Circuit-Board Extenders.

Perform the board removal procedure above, carefully install the board on the extender, and install the extender in the circuit board socket. (See Figure 5-2.) There are three extenders available as options. The K, C, and B boards must be extended for adjustments (Extender P/N 4215-2703). The S board must be extended for measurement points for adjustments (Extender P/N 4215-2701). All boards, except the Z and H boards, must be extended if it is desired to troubleshoot the parts on a board.

5.6.5 Display Modules and Lamps.

To remove a display module and to replace a lamp:

a. Pull up on the display module to unplug it from the H board.

b. Loosen the Phillips-head screw on the side of the holder and slide up the panel at the front of the module; this will expose the bulbs. Spare bulbs are socket-mounted beside symbol cut-outs. Remove the burned-out bulb (pry-up the base with a screwdriver) and the spare and make the replacement. Refer to the Parts List (F, G, or U module) if all the bulbs have been used. The F and G modules have spares, and these can be used in any of the modules. Reverse this procedure to reinstall the modules.

5.6.6 Readout Tubes.

The tubes unplug from the H board.

5.6.7 Transformer Plate Assembly.

WARNING

When the unit is energized, there is 250 V on parts under the cover. See Figure 6-24.

To gain access to parts in the transformer shield assembly, remove the four screws at the top of the case and remove cover.

5.6.8 Switch Removal - Replacement.

To remove knobs:

a. Set the controls full ccw.

b. Hold the instrument securely and pull the knob off with fingers.

CAUTION

Do not use a screwdriver or other instrument to pry off the knob if it is tight, since this might mar the panel. Do not lose the retention spring in the knob when the knob is removed.

c. Remove the setscrew from the bushing; use a hex-socket key wrench.

d. Remove the bushing.

NOTE

If the knob and bushing are combined when the knob is removed, turn a machine tap a turn or two into the bushing on the dial for sufficient grip for easy separation of the knob.

e. If the switch is to be removed, remove the dress nut exposed after step d.

Install the switches by reversing the removal procedure and performing the following steps:

a. Make sure the control shafts are turned full ccw.

b. Install the dress nut, if applicable.

c. Install the bushing on the shaft; tighten the setscrew.

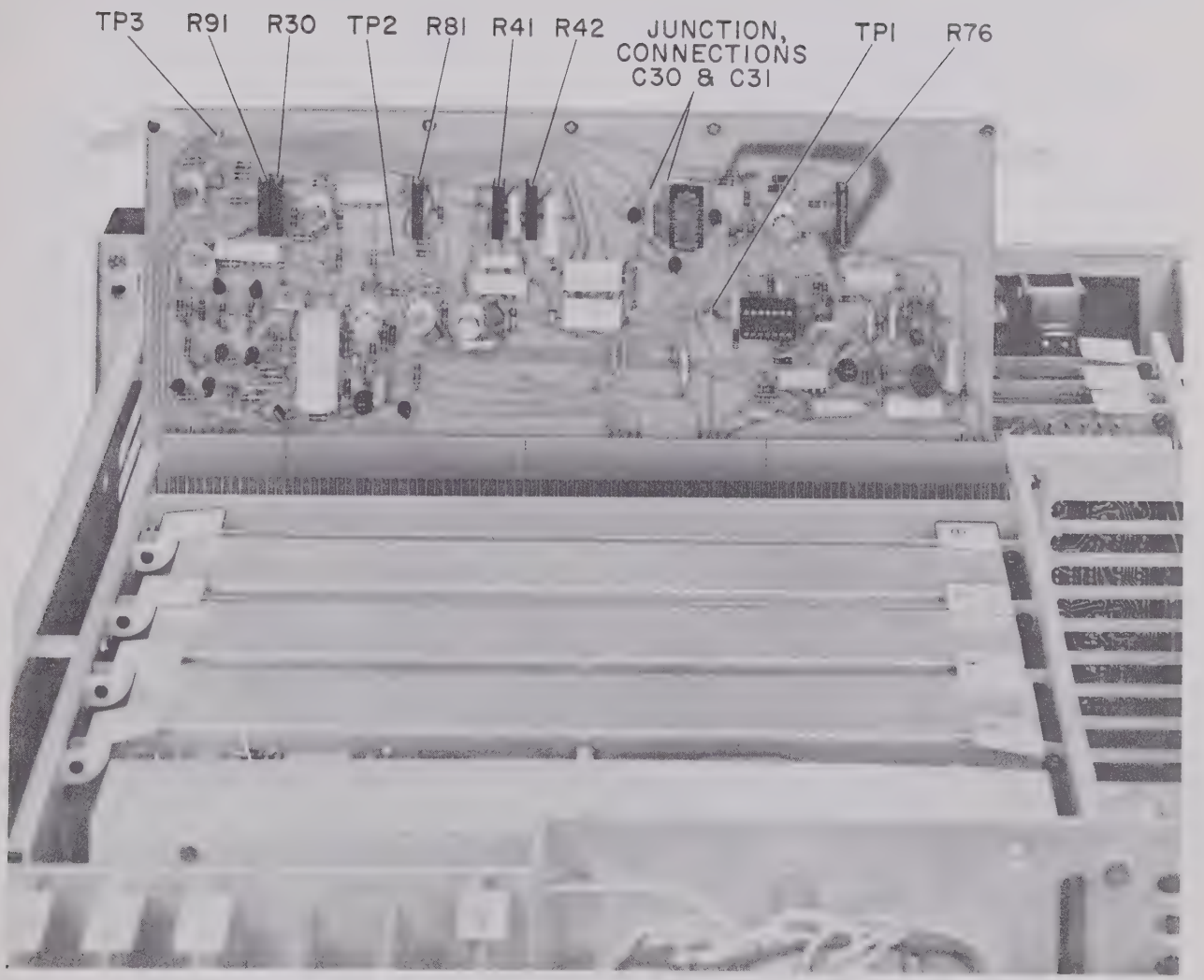


Figure 5-2. D board extended to show test points and adjustments.

NOTE

Make sure that the end of the shaft does not protrude through the bushing, or the knob won't seat properly.

d. Install the knob on the bushing, *making sure the retention spring is opposite the setscrew.*

NOTE

If the retention spring in the knob comes loose, reinstall it in the interior notch with the thin flange set into the small slit in the wall of the knob.

5.7 REFERENCE DESIGNATIONS.

All circuit boards are designated with a letter. Table 4-1 lists the boards and the letter designation. These are used on schematics and diagrams for easy identification of boards and parts. The latches on the circuit boards are marked with the letter for identification of the board.

Each signal name shown on schematics and the wire-run list is preceeded with a circuit board letter designation that identifies the origin of the signal. For example, signal QOSCOFF means the oscillator off (OSCOFF) signal from the Q (auxiliary) circuit board.

Each circuit board has its own sequence of parts reference designations, starting at 1. For example, R1, C1, etc. Front-panel or chassis-mounted parts designations are identified on drawings with the letter A preceding the designation; e.g., A-S1 or A-R1.

5.8 TEST POINTS.

5.8.1 Circuit Board Inputs and Outputs.

The input and output signals of every circuit board can be monitored at terminals on the bottom of the mother board. Remove the chassis from the cabinet according to paragraph 2.5 and set the instrument carefully on its side. The bottom of the mother board is marked with grids that section off in groups of five pins the circuit board pin connections that plug into sockets on the mother board. This provides identification of the input and output connections on the etched-boards and on the circuit schematics. The testing or monitoring device can be connected to the terminals.

A letter designation on the side of the mother board identifies the position of each circuit board. (Letter designations are used to identify boards; refer to paragraph 4.1). The E and C letters with the board designation letter identify the etched- and component-side board pin-connections.

5.8.2 Circuit Board Test Points.

Test points in the form of terminals provide access to significant points in a circuit are on the small- and intermediate-sized boards and on the D board. Most of the boards have the points at the top of the boards. The D and S boards have test points at other areas of the board. The S board must be extended to gain access to these points. The D board test points are available without extending the board. Figures 5-1 through 5-6 identify the points.

5.8.3 Anchor Terminals.

AT's are on the front and rear panels and on the bottom and top of the mother boards. Measurements can be also made at these points. These are identified by the designation AT. Those not identified on the panels are identified in Figure 5-5.

5.9 CIRCUIT BOARD INDICATOR LAMPS.

The program (P) and range (E) boards have indicator lamps mounted on the top of the boards for indicating the status of circuits in the instrument; e.g., the range in the automatic ranging mode, ranging upwards or downwards; counters counting forward or reverse; counter clock gates (main gates) enabled, anticipator function rising, decaying, stopping; and the state of the program board direction control flip-flops. Figure 5-6 shows the boards and identifies the lamps and their function.

Figure 6-4 is a functional flow diagram, showing the lamps and their relationship to the circuit functions. Not shown are the lamps (DS1-DS4) associated with direction control flip-flops on the program board. Figure 6-4 is an extremely useful aid in troubleshooting and can be used for a reference when a malfunction occurs.

With the mode switch TEST positions, the instrument can be made to count forward or reverse, and with the RANGE control, made to range automatically through ranges 1-9. The lamps can be observed for proper operation during these tests or during operation or when testing with a known standard.

CF, CR, GF and GR in Figure 6-19 are the Q outputs of the phase detector flip-flops. These lamps light (Table 5-4) when the outputs are logical "1"s. Signal DO is at pin 55C. The phase reference signals, S0, S90, S180, and S270 are from the reference circuit.

Table 5-4
PHASE-REFERENCE LAMPS

F-F Output	State of F-F	Lamp
GR(IC1) is:	"0" if DO is "1" @ 90°	DS1 "off"
	"1" if DO is "0" @ 90°	DS1 "on"
GF(IC2) is:	"0" if DO is "1" @ 270°	DS2 "off"
	"1" if DO is "0" @ 270°	DS2 "on"
CR(IC3) is:	"0" if DO is "1" @ 0°	DS3 "off"
	"1" if DO is "0" @ 0°	DS3 "on"
CF (IC4) is:	"0" if DO is "1" @ 180°	DS4 "off"
	"1" if DO is "0" @ 180°	DS4 "on"

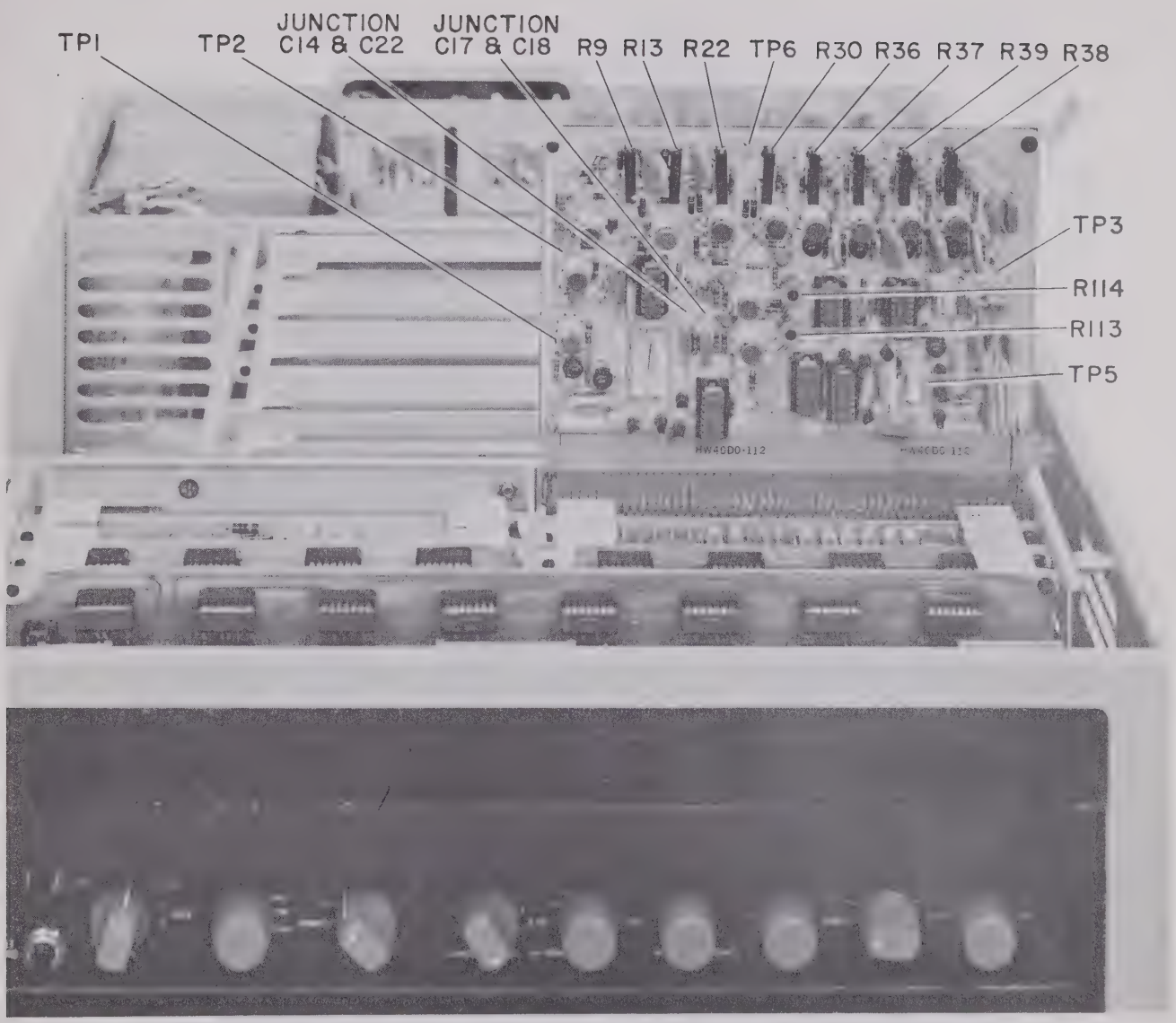


Figure 5-3. S board extended to show test points and adjustments.

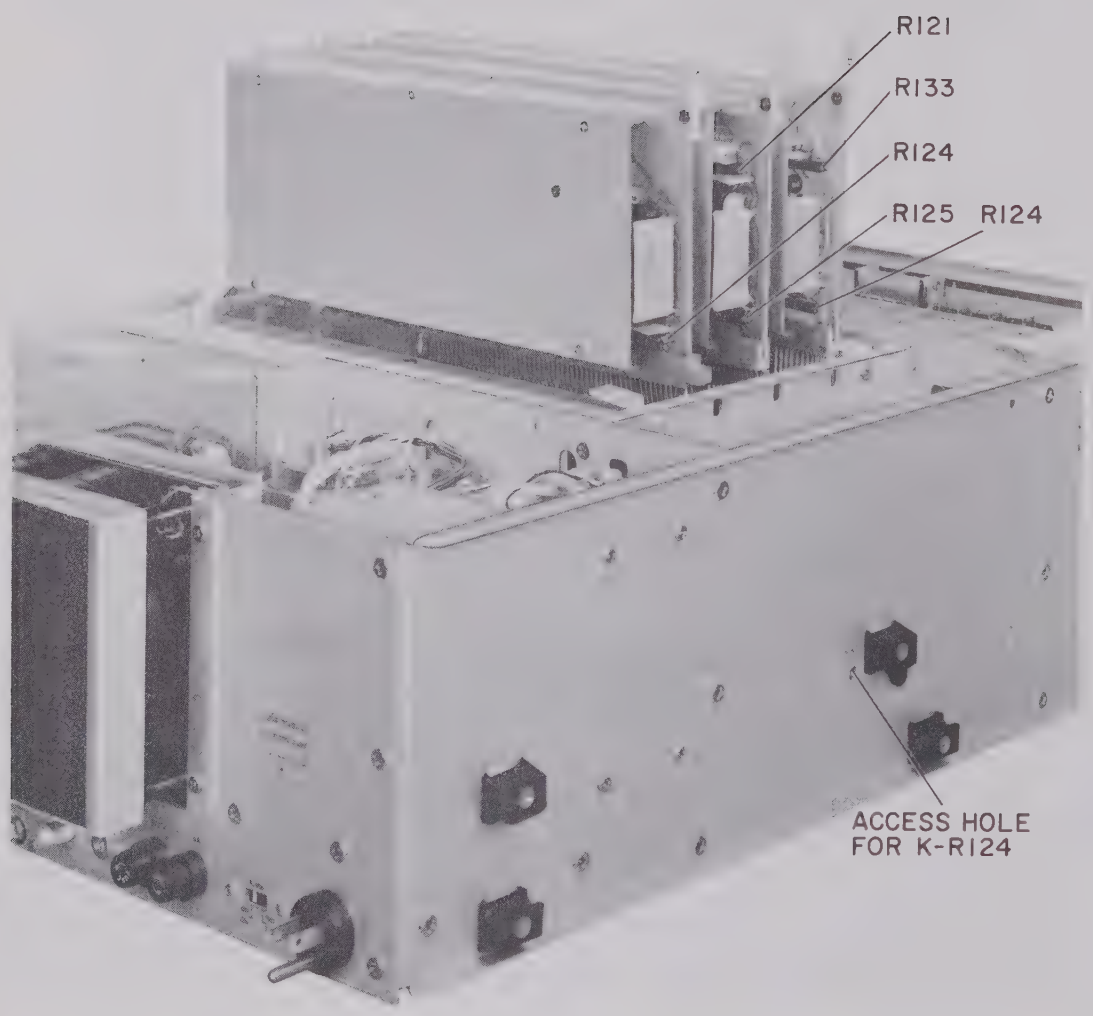


Figure 5-4. K, C, and B boards extended to show adjustments.

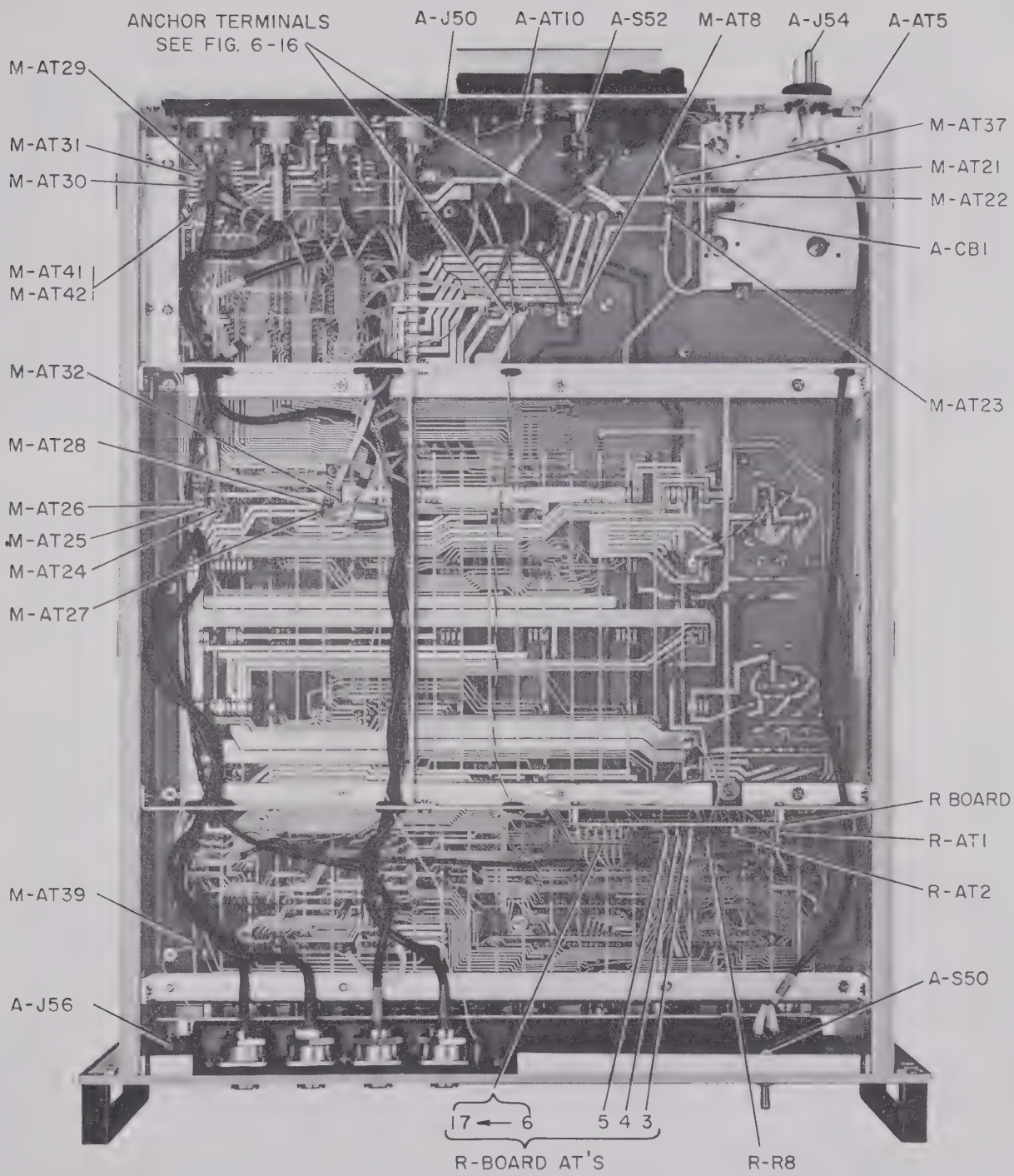
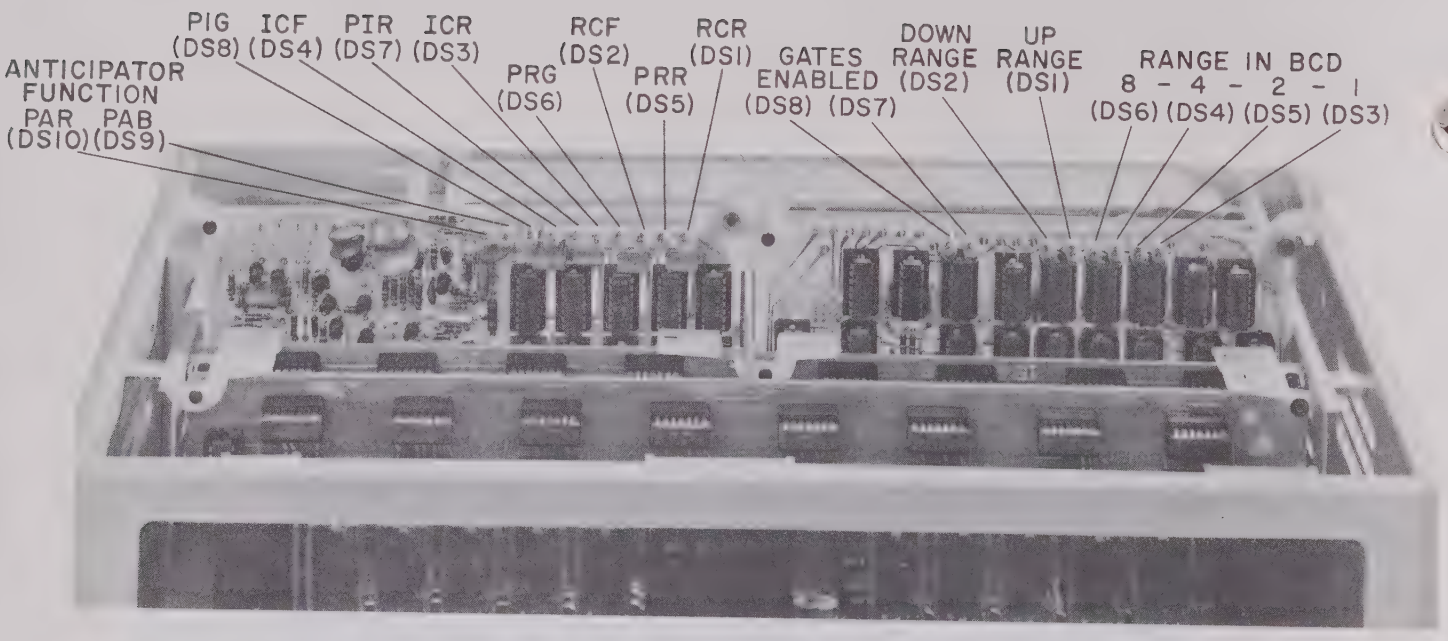


Figure 5-5. Bottom view of mother board.



P BOARD

DS1 (RCR)	LIGHTS WHEN SIGNAL DO IS "0" AT 90°.
DS2 (RCF)	LIGHTS WHEN SIGNAL DO IS "0" at 270°.
DS3 (ICR)	LIGHTS WHEN SIGNAL DO IS "0" at 0°.
DS4 (ICF)	LIGHTS WHEN SIGNAL DO IS "0" at 180°.
DS5 (PRR)	LIGHTS WHEN Ω OR D DISPLAY COMMANDED TO COUNT FORWARD.
DS6 (PRG)	LIGHTS WHEN MAIN GATE FOR 2I (R) COUNTER ENABLED FOR PASSING CLOCK PULSES.
DS7 (PIR)	LIGHTS WHEN H OR F DISPLAY COMMANDED TO COUNT FORWARD.
DS8 (PIG)	LIGHTS WHEN MAIN GATE FOR 1I COUNTER ENABLED.
DS9 (PAB) & DS10 (PAR)	ANTICIPATOR-FUNCTION CONTROL SIGNALS. LIGHTS WHEN LOGICAL "0". SEE TABLE IN FIG. 6-4

E BOARD

DS1 & DS2	LIGHT WHEN RANGE CHANGE OR POSSIBLE RANGE CHANGE OCCURS; DS1 INDICATES UP-RANGE; DS2, DOWN-RANGE.
DS3-DS6	INDICATE THE RANGE IN BCD; E.G., DS5 AND DS6 LIGHTED IS RANGE 6 (4 + 2). SEE TABLE 3-1 FOR RANGES.
DS7 & DS8	LIGHT WHEN APPLICABLE MAIN GATE IS PASSING CLOCK PULSES TO THE DISPLAY COUNTERS (I BOARDS).

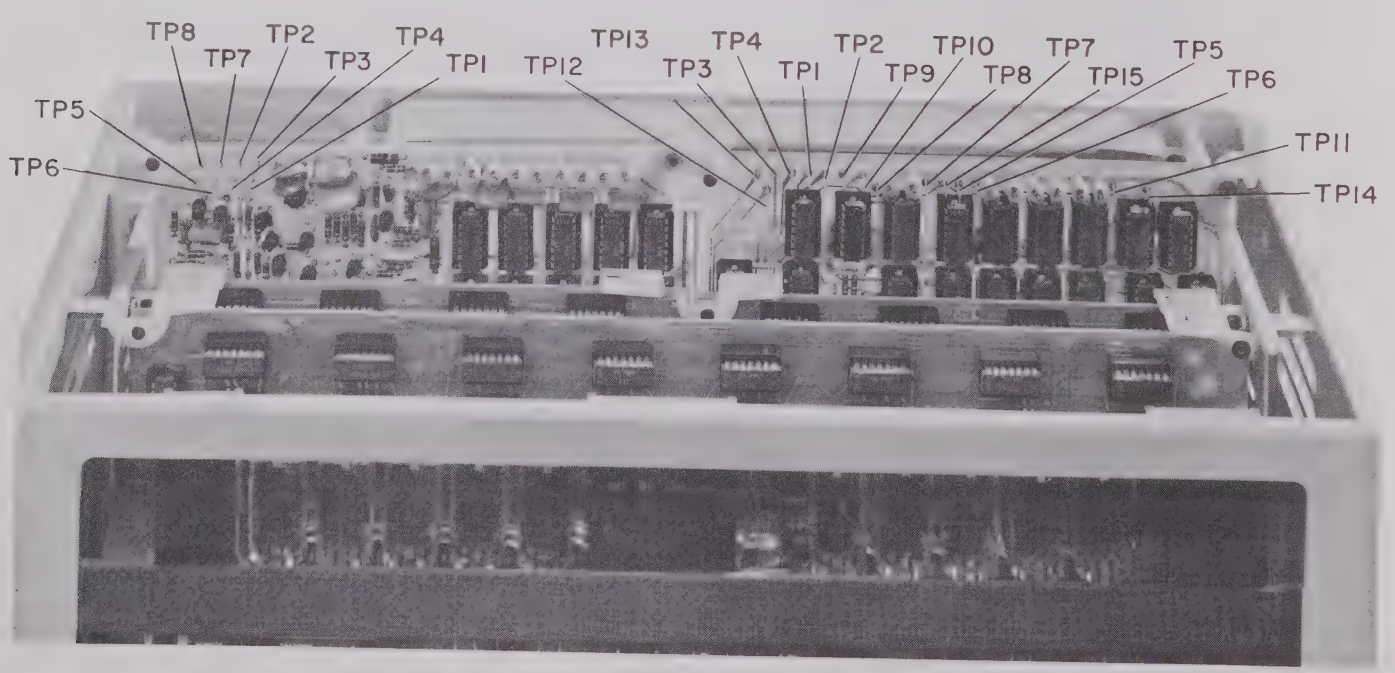


Figure 5-6. P- and E-board lamps and test points.

Table 5-5
LAMP STATUS

GR (DS1)	GF (DS2)	Function Being Performed	RF (DS5)	PRR	RCL (DS6)	PRG
OFF	OFF	Inhibit main gate for 2I (Ω and D) counter clock (close to balance)	ON	"0"	OFF	"0"
OFF	ON	2I counter and display count forward	ON	"0"	ON	"1"
ON	OFF	2I counter and display count reverse	OFF	"1"	ON	"1"
ON	ON	Inhibit main gate for 2I counter clock (balance achieved)	OFF	"1"	OFF	"0"
(DS3)	**(DS4)**		**IF (DS7)**	**PIR**	**ICL (DS8)**	**PIG**
OFF	OFF	Inhibit main gate for 1I (H and F) counter clock (close to balance)	ON	"0"	OFF	"0"
OFF	ON	1I counter and display count forward	ON	"0"	ON	"1"
ON	OFF	1I counter and display count reverse	OFF	"1"	ON	"1"
ON	ON	Inhibit main gate for 1I counter clock (balance achieved)	OFF	"1"	OFF	"0"

These signals set the four direction control flip-flops. The functions to be produced by these flip-flops (IC5-8) are 2I (Ω,D) counter count forward or reverse (DS5), inhibit or enable 2I counter clock (DS6), 1I (H, F) counter count forward or reverse (DS7), and inhibit or enable 1I counter clock (DS8).

Table 5-5 lists all the conditions for the phase detector flip-flops and the direction control flip-flops and their accociated lamps. The board output signals associated with the forward-reverse (PRR, PIR) and inhibit-gate (PRG, PIG) function of the direction control flip-flops are also listed. Note that, when signals PRR and PIR (the forward-reverse signals) are "0", the associated lamps DS5 and DS7 are on, whereas all other lamps are on when the signals is a "1". In this case, the lamps are not tied directly to the signal output but to the complimentary side of the flip-flops producing these signals.

The direction control flip-flops can be checked with the mode switch and the counters and displays made to count forward (F) or reverse (R). Table 5-6 lists the test sequence.

Table 5-6
F-F AND COUNTER TEST

Mode Switch TEST Position		DS5	DS6		DS7	DS8	
1	1I (H,F) Counter	—	OFF	Disable 2I	ON (F)	ON	Enable 1I
2	Check	OFF	OFF	Counter	OFF (R)	ON	Counter
3	2I (Ω, D) Counter	ON (F)	ON	Enable 2I	—	OFF	Disable 1I
4	Check	OFF (R)	ON	Counter	OFF	OFF	Counter

5.10 PERIODIC MAINTENANCE.

The fan filter and cabinet filters should be cleaned at least once a year, or sooner if operating in a dusty environment. The filters can be pulled right out of the holders without unfastening any parts. Wash the filters in soap and water or clean with a vacuum device.

The fan motor requires no lubrication. Keep the instrument cover, panels, controls and connectors and mother board clean and make sure connections to the instrument are clean.

5.11 CHECKS AND ADJUSTMENTS.

5.11.1 General.

The checks in this paragraph are for determining if the following circuit boards are operating properly. In some cases, only the major function of the board is checked; adjustments are included where applicable, so that the boards can be realigned if it appears they are out of adjustment. The checks are given in the order that a complete realignment should be performed or a maintenance check might be performed, if a fault (in all probability an inaccurate measurement that could not be resolved through the operational check in Section 3) could not be recognized immediately and corrected. Refer to Figures 6-3 and 6-4, which show the sequence. The divider accuracy checks can be performed periodically or when a failure of a resistor(s) in the divider weighted conductance network is suspected by the failure of the bridge to balance on only certain values, or counts. This is why this check is listed near the end of the check sequence and not after the power-amplifier check. The accuracy of the instrument and standards, operation of the counters, and range circuit board (E) are checked by the procedures listed in paragraph 5.4. The following checks and adjustments are included in this paragraph:

1. Power supply (V)
2. Oscillator (T)
3. Power amplifier (J)
4. Reference circuit (S)*
5. Detector circuit (D)
6. Reference circuit clock (signal SVCO)*
7. Dividers (K, B* and C*)
8. Leakage circuit (L).

To perform these checks, remove the chassis from the cabinet and turn the chassis on its side, so that the terminals on the mother board are available.

WARNING

Before attempting to check the instrument, refer to Figure 5-1, which points out the places where 250 V is present in the instrument when it is energized.

*Board must be extended for checks and/or adjustments.

Table 5-7
POWER SUPPLY CHECK AND ADJUSTMENT

M-Board Terminal	Adjustment	Voltage
V18E	V-R23	−15 V
V23E	V-R29	+15 V
V5E	—	+5 V
V38E	—	+10 V
MAT11	—	+15 V

5.11.2 Power Supply (V).

To check the power supply:

a. Connect one terminal of a voltmeter to ground (TG, pin V20E on mother board) and the other terminal to the mother board terminals listed in Table 5-7. Check for the voltages listed. Make the adjustment on the V board, as indicated, if the proper reading is not obtained.

NOTE

The supplies are interdependent. R23 must be adjusted first.

Rectifier circuits connected to the transformer secondary also provide + and −8 V for the power amplifier and 250 V for the numerical readout tubes. Be careful of the 250 V when checking an energized instrument. The 250 V is at the rectifier under the transformer shield assembly and at A-R52 and A-R54 at the top of A-C54, mounted at the rear of the instrument on the mother board. The 250 V is fed to AT1 on the H board by the wire running at the side of the chassis. On the H board the voltage is routed to the tubes by means of etched circuitry on the board. Refer to Figure 6-42 for checking these voltages. These need only be checked if the power amplifier fails (±8 V) or numerical readout tubes do not operate (250 V).

WARNING

If the H board is removed from the instrument, the 250-V connection, when removed from AT1, should be touched to ground to remove any possible charge on A-C54.

5.11.3 Oscillator (T).

a. Connect an oscilloscope and frequency counter to mother board terminal T5E.

b. Set the function control to 1 kHz and 120 Hz for any function and observe the readings listed in Table 5-8 for

Table 5-8
OSCILLATOR CHECK
AND ADJUSTMENT

Frequency	Adjustment	Reading
1 kHz	T-R1	1 kHz ±5 Hz
120 Hz	T-R2	120 Hz ±0.6 Hz

each frequency. Make the indicated adjustments if necessary. Observe the instructions in paragraph 2.3, if the line voltage is not 60 Hz.

The 120-Hz frequency should be exactly 120 Hz, since the oscillator is synchronized with 60-Hz line voltage. The amplitude of the voltage should be approximately 1 V rms.

5.11.4 Power Amplifier (J).

This check is for the test voltage (OSC LEVEL) and bias voltage.

a. Connect an oscilloscope to J35E (M Board), set the function switch to CsRs, set the OSC LEVEL control to maximum (2.21, and observe that the level is 6.2 V p-p. The reference line should also be 0 V, since the internal bias is disabled.

b. Adjust R20 on the T board, if necessary, to obtain 2.2 V rms.

c. Ground terminal T38E and adjust R7 on the J board, if necessary, to obtain a 0-V reference level.

d. Vary the OSC LEVEL control and observe that the voltage level changes according to the control markings.

e. Ground terminal J23E and increase the setting of the bias control; observe that the dc level increases and, at the maximum setting, the test signal is riding on a 3-V dc signal, above the 0-V base line.

f. Remove the ground connections.

5.11.5 Detector Circuit (D).

Filter Phasing and Anticipator. This check is for verifying the filter phasing and anticipator operation.

a. Connect a GR Type 1423 Precision Capacitor or equivalent to the 1683 and set it for approximately 1.005 μF; use a three-terminal connection (paragraph 3.1).

b. Connect the oscilloscope (channel 2) to terminal D33E (signal DE) and synchronize and trigger the oscilloscope (channel 2) with signal 0° at terminal S62C.

c. Set the function control to CsD 1 kHz, RANGE switch to 5, and allow the bridge to balance.

d. Vary the capacitor approximately ±1000 pF (10 counts) and observe that the cosine wave shown changes from a positive to negative cosine in the direction of the added or subtracted capacitance. The 0-V crossing of the wave should be at 90° and remain at 90° as the capacitance is varied (or the peak should stay at 180°). Figure 5-7 illustrates the waveforms that should be observed. The

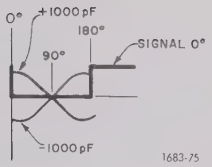


Figure 5-7. Filter Phasing.

waveforms shown are idealized waveforms. If the waveforms do not cross at 90°, adjust D-R41 to obtain the proper phase.

e. Set the RANGE switch to 6, the function switch CsD, 120 Hz, and allow the bridge to balance.

f. Vary the capacitor ±1000 pF and observe the indications specified in step d; adjust D-R42, if necessary, to obtain the proper phasing.

Output. To check and adjust the D-board anticipator, comparator, and squaring circuit:

a. Connect an oscilloscope to pin D41E (signal DO); leave the other channel connected to D33E (signal DE).

b. Connect an oscilloscope or voltmeter to TP2 on the D board and synchronize the oscilloscope with signal 0°.

c. With no capacitor connected to the 1683, ground pins 43C (PSTART) and P33E (PAR). Any signal at the anticipator (D-TP2) should go to 0 V, or at least to less than 1 mV. Adjust D-R30 if necessary, to obtain this reading.

d. Set the function switch to CsD 1 kHz.

e. Connect the capacitor, set it to approximately 1 μF, and allow the bridge to balance on range 5.

f. After the bridge balances, vary the capacitor ±1000 pF and observe that signal DO is a square-wave version of signal DE; that is, the signal going positive or negative at the 0-V crossings of the signal; adjust D-R81 if necessary, to obtain the proper signal.

Signal DEEE. To check the early error signal (DEEE) and its associated detectors:

a. Connect an oscilloscope to TP4 on the D board and set the function switch to CsD 1 kHz.

b. Allow the bridge to balance, using the 1423 Precision Capacitor set to approximately 1 μF. At balance, short-circuit signal DE to ground (use a short-length lead) and observe that the voltage at TP4 is 0 V; adjust R76 if necessary. (Only turn the adjustment to the point where the signal reaches the minimum level; do not turn the adjustment any further.)

c. With signal DE still grounded, connect the oscilloscope to pin D43E or TP3 on the D board (signal DEEE) and observe that the voltage is 0 V (at balance). If not, adjust D-R91 to obtain this reading.

d. Remove the ground from signal DE and reconnect the oscilloscope to TP4. With the capacitor set for 1 μF, allow the bridge to balance. After balance, vary the capacitor by +1000 pF and observe that the voltage increases.

e. Vary the capacitor again by +1000 pF (for a total of +2000 pF) and observe that the voltage increases by approximately the same amount as in step d. If not, adjust R76 until it does. This adjustment is not critical. However, if R76 is adjusted, perform step a again to ensure the voltage at TP4 is 0 V when the bridge is at balance and signal DE is grounded.

If signals DE and DEE are not present, perform the troubleshooting procedure in Table 5-17.

5.7.6 Reference Circuit (S).

This check is to ensure that the proper phase-reference signals (0°, 90°, 180°, and 270°) are produced by the reference circuit.

a. Connect the +CURRENT terminal to the +POTENTIAL terminal using the supplied cable or jumpers with allegator clips and set the function switch to CsD 1 kHz; set the OSC LEVEL control to minimum.

b. Connect the oscilloscope to the mother board terminals listed in Table 5-9 and observe the phase-reference indicated. Synchronize the oscilloscope (channel 1 input) with signal KV (sinewave going negative at 0°, pin S60E) or signal YV (sine wave going positive at 0°, pin Y1C). Trigger the oscilloscope on either of these signals. Note that if signal YV is used for the sync, the signals listed in Table 5-9 will be inverted. Signal KV must be present for the circuit to operate. If it isn't, check the K board, according to the procedure in Table 5-17. If the proper signal is not observed, make the adjustments indicated in Table 5-9.

5.11.7 Reference-Circuit Clock.

The operation of this circuit depends on the proper signals (DE and DEE) being received from the detector board. These signals are checked in the preceding paragraph. The S board must be extended for this check.

a. Remove the J, K, and D boards from the unit and set the SENSITIVITY control to its maximum position.

b. Set the function control to any position and turn on the instrument.

c. Ground inputs KV (S60E), DE (S87E) and DEEE (S88E).

d. Connect an oscilloscope to S-TP7 and observe the voltage is 0 V. If not, adjust R22 to obtain this reading.

e. Connect the oscilloscope to TP3 and observe that the voltage is 0 V. If not, adjust R114 to obtain this reading.

f. Connect the oscilloscope to TP8 and observe that the voltage is 0 V. If not, adjust R30 to obtain this reading.

g. Connect the oscilloscope to TP4 and observe that the voltage is 0 V. If not, adjust R113 to obtain this reading.

h. Connect the oscilloscope to TP's 9 through 12 and observe that the voltage at each test point is 0 V. If not, adjust R36 through R39 respectively, to obtain this reading.

i. Remove the grounds from KV, DE, and DEEE and re-install the circuit boards, making sure they are seated properly.

j. Disconnect the lead from AT1 on the auxiliary comparator board (R board) on the bottom of the mother board (see Figure 5-5) and ground *the lead*.

NOTE

The clock frequencies can be checked at the same time the next portion of this check is being made. Refer to the procedure in the next para.

k. Connect a low-loss 500- to 800-pF variable air capacitor (a GR Type 1422-D is recommended) to the bridge and set the mode switch VARIABLE MEAS RATE, RANGE switch to range 8, function switch to CsRs 1 kHz, and OSC LEVEL to 2.2.

l. Connect a Tektronix type 547 oscilloscope with a 1A1 dual-trace preamplifier or 1A4 four-trace preamplifier (preferable) to the bridge. Connect channel 1 to signal YC at the Y board (ground the probe to YG) and trigger the oscilloscope with signal YC.

m. Connect channel 2 to connection D33E (signal DE) and display both channels. On the display, extend signal YV to display 1 or 2 cycles.

n. Connect another channel or oscilloscope to connection S109C (signal SBAL).

o. With the bridge set for the VARIABLE MEAS RATE mode and the FAST-STOP-SLOW control set to STOP, press the START switch and allow the bridge to balance.

p. Using the TEST 1, 2, 3, and 4 switch positions, make the error signal (DE) decrease to its minimum level. (The signal will look noisy and have ripple on it.) This is the balance, or null, condition. At the minimum level, note the reactance display reading. Also note that signal SBAL is a logical "1" at balance.

Table 5-9
REFERENCE SIGNALS AND ADJUSTMENTS

M-Board Terminal	Adjustment	Signal
S62C	S-R13	Negative-going at 0° and positive-going at 180°
S63C	—	Negative-going at 180° and positive-going at 0°
S60C	S-R9	Negative-going at 90° and positive-going at 270°
S61C	—	Negative-going at 270° and positive-going at 90°

Table 5-10
SVCO CLOCK FREQUENCY CHECK

Step	Oscilloscope Connections	Function Control	Range	Increase Error Count (Nominal) After Balance by	Observe When Error is Increased	
					Signal	SVCO is
1	S109C & S111C (SBAL) (SVCO)	CsD 1 kHz	8	1-2	SBAL goes to "0". If not, adjust R36.	400-600 pps while error is being balanced.
2		CsD 120 Hz	9	1-2	---	40-60 pps while error is being balanced.
3	S88C & S111C (SUNBAL) (SVCO)	CsD 1 kHz	8	10	SUNBAL goes to "1". If not, adjust R37.	4-6 kpps until error is 10 counts.
4		CsD 120 Hz	9	10	---	400-600 pps until error is 10 counts.
5	S111C (SVCO)	CsD 1 kHz	8	100	---	40-60 kpps until error is 100 counts. If not, adjust S-R38.
6		CsD 120 Hz	9	100	---	4-6 kpps until error is 100 counts.
7	S111C (SVCO)	CsD 1 kHz	8	500	---	400-600 kpps until error is 500 counts.
8	S111C (SVCO)	CsD 120 Hz	9	500	---	40-60 kpps until error is 500 counts.

q. Using mode switch position TEST 1, advance the count by 1 count. SBAL should go to "0" or be on the threshold of going to "0." Using switch position TEST 2, bring the bridge to balance again (the original reading). SBAL should go to "1.

r. Again using the TEST 2 switch position, go back two counts. SBAL should then go to "0." In any event, SBAL should be a "1" for 3 counts, either one forward and two reverse from null (balance) or two forward and one reverse from null (which is 1.5 counts). If this indication is not obtained, adjust R36 until it is obtained.

s. Connect the oscilloscope to S88C (SUNBAL) and repeat the procedure in step r, except SUNBAL should go from "1" to "0" when the display reads from 8 to 12 counts on either side of null (minimum DE signal). Also, note that signal SUNBAL is produced by the auxiliary comparator board, at this time. This output can be checked using the procedure described further on in this paragraph for checking the comparator board.

t. In a similar manner the "error-less-than-100-counts" comparator circuit (IC11) and 500 counts comparator circuit (IC12) can be checked by offsetting the balance by

Table 5-11
LEAKAGE-CURRENT CHECK

Leakage-Current Range	Applied Voltage (V)	Series Resistance (Ω)	Current	Voltage at TP1 (V)	ZLEAK at L2E (V)
1 μA	1	10 M	0.1 μA	0.1 ±10 mV	0.4
1 μA	1	1 M	1.0 μA	1 ±20 mV	4
1 μA	2.5	1 M	2.5 μA	2.5 ±50 mV	10
10 μA	1	1 M	0.1 μA	0.1 ±10 mV	0.4
10 μA	1	100 k	10 μA	1 ±20 mV	4
10 μA	2.5	100 k	25 μA	2.5 ±50 mV	10
100 μA	1	100 k	10 μA	0.1 ± 2 mV	0.4
100 μA	10	100 k	100 μA	1 ±20 mV	4
100 μA	25	100 k	250 μA	2.5 ±50 mV	10
1 mA	10	100 k	100 μA	0.1 ± 2 mV	0.4
1 mA	10	10 k	1 mA	1 ±20 mV	4
1 mA	25	10 k	2.5 mA	2.5 ±50 mV	10
10 mA	10	10 k	1 mA	0.1 ± 2 mV	0.4
10 mA	10	1 k	10 mA	1 ±20 mV	4
10 mA	25	1 k	25 mA	2.5 ±50 mV	10

approximately 100 counts and 500 counts, respectively, and observing that the output of the respective inverter connected to the comparator goes to "0" when the error is less than *approximately* 100 counts and 500 counts respectively.

Clock Frequencies. The clock frequencies can be checked using the procedure above for checking the S-board comparator outputs. However, instead of checking the outputs of the comparators for a change in state as the error is increased or decreased, an oscilloscope or counter can be connected to S111C (signal SVCO) and the change in frequency observed as the error is increased or decreased using the mode switch TEST 1-4 switch positions. Table 5-10 lists the clock frequencies for the different amounts of error at both the 1-kHz and 120-Hz test frequencies. Note that a range change is required when checking the 120-Hz.

Auxiliary Comparator Check. Use the same setup that was used for the SBAL comparator in the Output Check. The wire on AT1 of the comparator board (Figure 5-5) should be disconnected from AT1 and ***the wire*** grounded to the chassis. Also, a low-loss 500- to 800-pF variable air capacitor should be connected to the bridge.

a. If a four-trace oscilloscope was used, connect channel 3 to D-TP2 (D3E, anticipator output) and trigger the oscilloscope with this signal. The signal can be observed with a time-base setting of about 20 ms/cm.

b. Connect channel 4 to AT1 on the auxiliary comparator board. Set the function switch to CsD 1 kHz and mode switch to VARIABLE MEAS RATE.

c. Press the SET ZERO switch and then the START switch and allow the bridge to balance. At balance, adjust R8 so that AT1 goes from "0" to "1", then back off slightly just to the point where AT1 goes from "1" to "0" (when the START switch is pressed). Reconnect the wire to AT1. If it is desired to check the board output at AT112 (this signal goes to the S-board SUNBAL output) connect the oscilloscope to AT7 and observe that the signal goes from "1" to "0" just before balance (approximately within 8 to 12 counts of error).

5.11.8 Leakage-Current.

a. With no unknown connected to the terminals, set the LEAKAGE controls to the 1-μA range and the variable control ccw to minimum setting.

b. Ground terminal L24E ($\overline{\text{PLEAKOFF}}$), connect an oscilloscope to L-TP1, turn on the instrument, and observe that the voltage is 0 V ±1 mV. If not, adjust L-R6 to obtain this reading.

c. Set the LEAKAGE control to the 10-μA range and observe that the voltage at TP1 is 0 V. If not, adjust L-R29. Repeat steps b. and c.

d. Set the LEAKAGE control back to 1 μA.

e. Connect a GR Type 1434-P Decade Resistor, or equivalent, in series with a 0 - 10-V power supply to the –CURRENT terminal.

f. Connect a voltmeter to terminal L2E and an oscilloscope or voltmeter to L-TP1 and L-TP3.

g. Set the decade resistor to 10 MΩ and the external power supply to 1 V, so that there is a 0.1-μA input to the L board; the voltage at TP1 should be 0.1 V ±10 mV.

h. Initiate a leakage-current measurement at a very slow rate and turn-up power supply voltage, so that the voltage at terminal L2E is 0.4 V; observe that TP2 goes to "0" when the 0.4-V level is reached. If not, adjust L-R14 so that it does.

Table 5-12
K-DIVIDER CHECK

Reactance Display Reading	Divider Network "0" Inputs (Schematic Fig. 6-14.)	
	Input*	Pin No.
1000.0 nF	1$\overline{Q0}$	79E
0800.0 nF	1$\overline{Q1}$	64C
0400.0 nF	1$\overline{Q2}$	65C
0200.0 nF	1$\overline{Q3}$	77C
0100.0 nF	1$\overline{Q4}$	78C
0080.0 nF	1$\overline{Q5}$	48C
0040.0 nF	1$\overline{Q6}$	49C
0020.0 nF	1$\overline{Q7}$	62C
0010.0 nF	1$\overline{Q8}$	63C
0008.0 nF	1$\overline{Q9}$	32C
0004.0 nF	1$\overline{Q10}$	33C
0002.0 nF	1$\overline{Q11}$	46C
0001.0 nF	1$\overline{Q12}$	47C
0000.8 nF	1$\overline{Q13}$	16C
0000.4 nF	1$\overline{Q14}$	17C
0000.2 nF	1$\overline{Q15}$	30C
0000.1 nF	1$\overline{Q16}$	31C

*To obtain a "0" for the lower-value inputs, the display must read exactly as indicated in the "Reactance Display" column (no error). Adjust the capacitor or use the mode switch TEST 1 or 2 switch positions to set the display for the exact reading, if necessary. Using the same mode switch positions, offset the reading and observe the input goes back to "1". (A digit 4 must be offset to a 6 or 3.)

i. Perform the same operation for all the ranges listed in Table 5-11. Set the decade resistor and the power supply to obtain the current listed and the resultant voltage at TP1. For the first two ranges, increase the LEAKAGE variable control (ZLEAK) during the measurement to the voltage indicated and observe that TP2 goes to "0" at that point and that the GO indicator lights. This should only be necessary for the first two ranges; adjust R14 if necessary. Make the measurement at TP1 for all ranges to verify proper operation at each range if need be. ZLEAK need not be applied for these remaining checks.

5.11.9 Divider Checks.

General. Perform the following checks when trouble is suspected in any of the divider boards by reason of the failure of the bridge to balance on a certain value or values (indication of the failure of a part of the board ladder network) or the failure to balance a particular type component (resistor, capacitor, etc.).

CAUTION

Do not bend a resistor card on divider board when testing or repairing the board.

K-Divider Board. This board is associated with reactance measurements. To check the ladder network linearity:

a. Connect one channel of a dual-trace oscilloscope to the K-divider board output (KM), set the function switch to CsD 1 kHz, and RANGE switch to 7.

b. Connect a 10,000-pF capacitor to the bridge terminals.

c. Press the SET ZERO switch and observe that displays read all zeros. If not, a possible fault exists in the counter circuits or display circuitry.

d. With the oscilloscope set for high sensitivity, use the mode switch TEST 1 position to count the reactance display up (forward) to a maximum count of 19999 and TEST 2 switch position to count the display back down (reverse) to all zeros. When doing this, the oscilloscope sensitivity will have to be changed accordingly to fully observe the signal. Observe that the signal increases and decreases linearly as the display is counted forward and reverse.

If any nonlinearity is encountered, refer to Table 5-12. Using the mode switch TEST 1 and 2 positions, the display can be set to any of the readings listed in the "Reactance Display" column, to verify that signals are present at all the

Table 5-13
B-DIVIDER CHECK

Resistance Display Reading	B-Divider Network "0" Inputs (Schematic, Figure 6-5.)	
	Input*	Pin No.
1000.0 Ω	$2\overline{IQ0}$	81E
0800.0 Ω	$2\overline{IQ1}$	64E
0400.0 Ω	$2\overline{IQ2}$	65E
0200.0 Ω	$2\overline{IQ3}$	78E
0100.0 Ω	$2\overline{IQ4}$	79E
0080.0 Ω	$2\overline{IQ5}$	48E
0040.0 Ω	$2\overline{IQ6}$	49E
0020.0 Ω	$2\overline{IQ7}$	62E
0010.0 Ω	$2\overline{IQ8}$	63E
0008.0 Ω	$2\overline{IQ9}$	32E
0004.0 Ω	$2\overline{IQ10}$	33E
0002.0 Ω	$2\overline{IQ11}$	46E
0001.0 Ω	$2\overline{IQ12}$	47E
0000.8 Ω	$2\overline{IQ13}$	16E
0000.4 Ω	$2\overline{IQ14}$	17E
0000.2 Ω	$2\overline{IQ15}$	30E
0000.1 Ω	$2\overline{IQ16}$	31E

*Refer to the footnote under Table 5-12.

Table 5-14
C-DIVIDER CHECK

Reactance Display Reading	C-Divider Network 9-V Inputs (Schematic, Fig. 6-6)	
	Input	Pin No.
100.00 nF	KS0	79E
080.00 nF	KS1	65E
040.00 nF	KS2	64E
020.00 nF	KS3	77E
010.00 nF	KS4	78E
008.00 nF	KS5	49E
004.00 nF	KS6	48E
002.00 nF	KS7	62E
001.00 nF	KS8	63E
000.80 nF	KS9	33E
000.40 nF	KS10	32E
000.20 nF	KS11	46E
000.10 nF	KS12	47E
000.08 nF	KS13	17E
000.04 nF	KS14	16E
000.02 nF	KS15	30E
000.01 nF	KS16	31E

inputs or at the particular segment of the matrix and ladder network in which nonlinearity is indicated. The schematic shows the portion of the matrix and ladder network and related input signals and display digits. Also refer to para. 4.4.5 if necessary. If the proper input is present, a failure has probably occured in one of the areas associated with the input switching signal. If the proper signal is not present, a failure has probably occured in the 1I counter or interconnecting wiring. If the displays work properly, the fault is probably in the interconnecting wiring.

If no reactance display reading occurs or trouble is suspected with the K divider, perform the following to check the board's output amplifier and board gain:

a. Connect one channel of an oscilloscope to the K-divider board output (KM) and the other channel to the input (YV).

b. Set the function switch to CsD 1 kHz and use the mode switch TEST 1 and 2 switch positions to make the reactance display read 10000.

c. Connect a 10,000-pF capacitor to the bridge terminals and observe on the oscilloscope that the output signal is of the same amplitude as the input signal. Note that the gain of the board is 2; therefore, when the display is set to 10000, the gain is one-half, or 1.

If the above fault indications are observed the board must be replaced or repaired. ***Do not attempt to make an adjustment on any divider boards.*** This should be done by a GR Service Facility.

B-Divider Check. Check the B divider in a similar manner as that described for the K board. However, set the function switch to LsRs 1 kHz and connect a low-value resistor to the bridge terminals. Use Table 5-13 to check inputs to the board matrix and ladder networks, if nonlinearities are encountered and it is desired to verify that signals are present at the inputs to these networks. If all the signals are present, a fault probably exists in the board network. If a signal is missing, check the appropriate 2I counter outputs and interconnecting wiring.

To check the board's output amplifier and board gain, set the resistance display to 10000 using the mode TEST 3 and 4 switch positions. (The gain of the board is approximately 2.) Refer to the schematic and use a similar test as that described for the K divider.

C-Divider Board. Check this board in a similar manner as that described for the K divider, except connect a 10,000-pF capacitor to the bridge terminals and set the function switch to CsRs 1 kHz and RANGE switch to 7.

Use the mode switch TEST 1 and 2 positions to count the reactance display forward to 19999 and then back down to 00000. If nonlinearity is encountered, use the display settings listed in Table 5-14 to see if inputs to the board matrix and ladder networks from the K-divider board are present. To check the inputs, the display must read the exact count specified in the "Reactance Display" column. When the display reads the exact count, approximately 9 V will be at the specified input-pin connection. After obtaining the exact reading, offset the reading using the TEST 1 and 2 mode switch positions and observe that the voltage goes to approximately −13 V when the display changes.

To check the board's output amplifier and board gain, use a similar method as that described for the K board. However, set the reactance display to 19999. Note that this display setting is different from the ones required for checking the other boards. Check the board by setting the function control to both the CsRs 1 kHz and CsRs 120 Hz and check that the gain is 0.628 for 1 kHz and 0.754 for 120 Hz, as compared to the input signal at input YC.

5.12 TROUBLE ANALYSIS.

5.12.1 General.

Procedures are included here to isolate a fault to an etched-circuit board. Once the fault has been isolated to a board or boards, a replacement can be obtained quickly by using the procedure specified in paragraph 5.3. If it is desired to isolate a fault to a part on the board and then repair the board, the information in the theory description of the board in Section 4, waveforms and voltage levels on the drawings in Section 6, and the Parts List for the board, allow isolation to a part on the board and repair of the board.

5.12.2 Troubleshooting Aids and Data.

The block diagrams of each circuit board shown in Section 4 are very useful in isolating a fault to a board, if any trouble is encountered during troubleshooting. Figure 6-4, the functional flow diagram, and the lamps on the P and E boards are also useful for troubleshooting. (Refer to paragraph 5-9.)

In most cases when an IC fails, its output voltage will not be 0 V or +5 V but will most likely be somewhere around 2 V. When checking signals and this voltage level is encountered, it will probably indicate that an IC output connected to, or used to produce the signal, has failed. Also, relays are more likely to fail than other circuit parts. A normal logical "1" level is +3.5 V to +5 V and "0" levels is approximately ground.

Table 5-15 lists the most probable faults that can occur in the instrument, the probable cause, and the procedure to

remedy the fault. All possible faults are not included, but any other possible faults that could occur would usually be associated with a circuit board. Since each board has a certain function, the area of the fault can be isolated quickly.

For a catastrophic failure, such as the bridge does not balance but the displays are lit, the best method of troubleshooting would be to first use the mode switch TEST positions to exercise the counters and displays, isolating any possible fault to these circuits. The next step, if these circuits are operating properly, is to use the lamps on the P board to isolate faults to that board. If this board is operating properly the next check would be at the D board output to see if the proper signals are present. If they are not, the fault is in the D board or circuit boards preceding it. If the signal is present, the fault must be in the S board. Tables 5-16 and 5-17 give the procedures to follow if this type of fault has occurred.

Before attempting to troubleshoot, check that the circuit boards are properly seated and secured in their sockets. Also check for bent pins on the bottom of the mother board that may be touching each other.

5.13 SERVICING ETCHED-CIRCUIT BOARDS.

It is recommended that etched-circuit boards be replaced, when found to be faulty. (Refer to paragraph 5.3.)

Table 5-15
FAULT INDICATIONS, CAUSES, AND REMEDY

Fault Indication	Probable Cause	Remedy
Displays light but do not count.	Circuit board failure.	Refer to paragraph 5.12.2 and Table 5-16.
Displays do not light.	Power supplies.	Refer to paragraph 5.11.2.
Display(s) count but do not change range.	Range board (E) faulty or counter board(s) faulty (do not produce proper range-change signals for E board).	Refer to Table 5-19.
Displays only range up or down to a certain range or skip a range in the automatic ranging mode.	E-board range counter if range inhibited. Range counter, Z-board range matrix, or numerical readout tube(s) if range is skipped.	Refer to Table 5-19. If the range counter or its decoder is faulty, however, there should be an error of a factor of about eight, since a Y-board relay(s) will not be energized.
Slight error is observed consistently for different unknowns.	For dissipation factor, R133 on B-divider board out of adjustment.	Factory adjustment. Do not adjust.
	For resistance, R125 and/or R121 on C-divider board out of adjustment.	Factory adjustment. Do not adjust.
	For capacitance at 1 kHz, compensation standards M-C12-C14.	Make sure that there is no stray capacitance present according to para. 3.13. Then adjust M-C14, using step 1 of the procedure in Table 3-3. M-C11 to C13 are adjustable by substituting capacitors.
	For capacitance at 120 Hz, compensation standards M-C10 or M-C11.	Make sure that there is no stray capacitance present according to paragraph 3.13. Then adjust M-C10 and/or C11 according to step 1 of Table 3-3. M-C10 and C11 are adjustable only by substituting different value capacitors.
Large error is observed consistently for different unknowns.	Reference levels produced by signals DE and DEEE at S board not correct.	Refer to para. 5.11.5 (parts 2 and 3) and 5.11.7.
Large error but in multiple of approximately eight; e.g., 0.8, 8, 80, 800, etc.	Y-board range relay(s) not activated when in the automatic ranging mode.	Check that a "0" is at the appropriate pin input (see Figure 6-26) of the Y board. If the proper signal is present, the Y board is faulty. If not present, check the output of the E-board range counter to see if the counter and/or its decoders are faulty.
Displays stop counting and UNBALANCED lamp is lit.	Anticipator generator on D board not functioning properly or display counter not functioning properly.	Check the operation of the counters, using the mode switch TEST positions. Check the anticipator generator according to paragraph 5.11.5, part 2. Use Table 5-20 to troubleshoot the anticipator if necessary.

Table 5-15 (Cont)
FAULT INDICATIONS, CAUSES, AND REMEDY

Fault Indication	Probable Cause	Remedy
Error is observed for some unknowns of the same type and value or other unknowns of the same type but different values. The error observed will usually be in the form of the bridge "hunting" to either side of a numeral or between a digit or digits; for example, between the units and tens or between thousands, tens, units, etc.	Faulty component in any arm of a divider board or failure in signal line from counter. A catastrophic failure will probably result in the "hunting" effect. Other failures may result in errors only for certain values of unknowns.	Refer to paragraph 5.11.9 and Table 5-12 for CsD, Table 5-14 for CsRs and Table 5-13 for LsRs. If just checking for a faulty part, the full check in the table need not be performed. Check the digit or digits affected. If the counter signals are present, the board is faulty. If the signal(s) is not present, trace the signal to locate the fault.
Bridge balances slowly.	Phase-reference signals produced by S board are out of phase.	Refer to para. 5.11.6.
	Anticipator-generator on D board not turned on (stays at 0 V) or generator driver (P board) not operating.	Refer to paragraph 5.11.5. If the generator is not operating properly, refer to Table 5-20.
	Possibility SVCO clock signal is on lowest frequency.	Refer to Figure 6-22 and Table 5-10; check that clock frequencies are as listed.
Bridge down-ranges only or gives down-range indication when it should not.	Oscillator may not be turned off during a range change. This may cause the amplifiers on the Y board to saturate, producing signal $\overline{\text{YDOWN}}$, which causes the range circuit to range downwards when the Y-board amplifiers are saturated. $\overline{\text{YDOWN}}$ may stay "0", inhibiting the upranging of the bridge.	Check signal $\overline{\text{YDOWN}}$ does not stay "0" as bridge down-ranges. If it does, check that signal $\overline{\text{ECHANGE}}$ turns off the oscillator (Fig. 6-23). If so, and $\overline{\text{YDOWN}}$ remains "0", Y board may be faulty or there may be a wiring fault. If $\overline{\text{YDOWN}}$ is allright, signals $1\overline{\text{IOR}}$ or $2\overline{\text{IOR}}$ may be causing the bridge to down-range, or the E-board range circuit may be faulty. Check these according to Table 5-16, step 2, "Signal Present."
Bridge persistently up-ranges.		Counter signals I00 or $\overline{\text{I9F}}$ may have failed or range circuit is not operating properly. Check according to Table 5-19.
Groups of digits or numerals blank out.	H-board circuits or wiring between counters and displays.	Refer to Figures 6-9 to 6-12. Faulty circuits can be determined by relating the BCD lines to the H-board circuitry.
Rate between measurements can't be varied or can't be varied properly.	VARIABLE MEAS. RATE control and/or wiring, P-board VMR generator, or VMR generator rate not slowed (for leakage-current) or turned off by 'N' and 'B' outputs of F-F E-IC28.	Check VARIABLE MEAS. RATE switch and wiring and VMR generator.
Dual or shadow numerals on readout tubes.	Defective IC decoders on H board.	Replace board or faulty IC's.

Table 5-16
TROUBLESHOOTING – DISPLAYS LIGHT BUT DO NOT COUNT

Step	Procedure	Signal Present	Signal Not Present
1	Make sure the SENSITIVITY control is not turned to the MIN position.		NOTE If the displays count up to a certain point, can be reset to all zeros, or just some displays reset to zero, the counter board is probably faulty.
2	Check that signal $\overline{PRIG}$ at P-TP5 goes to "1" after the start is initiated for a balance (not TEST) operation or signal goes to "0" for 15 ms after start, then goes to "1".	Proceed to step 3.	Indicates that start circuit on P board may not be functioning properly. Proceed to step 7.
3	Use the mode switch TEST positions (Table 5-6) to check circuitry. Check that P-board lamps DS5-DS8 light in the sequence listed in Table 5-6.	If the lamps light and the displays count, proceed to step 4. If the lamps light but the displays do not count, proceed to step 5.	If the lamps do not light, check P-board output signals PRR, $\overline{PRG}$, PIR, and $\overline{PIG}$, as listed in Table 5-5 for the various mode TEST positions. If the proper signals are not present, the P board is faulty. If present, a lamp has failed; therefore, proceed to step 4.
4	Connect a capacitor or resistor to the bridge and allow the bridge to balance slowly. Observe that P-board lamps DS1-DS4 flash or glow.	If the lamps flash or glow, check that signal SVCO is present at (P29E) during a balance operation and that signal PCLK12 is present at P-TP3. (See Fig. 6-32.) If SVCO is present and PCLK is not, the P board is probably faulty. If SVCO is not present, check (para. 5.11.5) signals DE and DEEE. If the signals are not present, perform the procedure in Table 5-17. If the signals are present, check their inputs to the S board. Also, check that signal KV is present at the input. If present, check the S board according to para. 5.11.6, and 5.11.7 to make sure that the S board is the faulty board.	Check that signal DO is present at the D-board output. Refer to para. 5.11.5. If not, perform the procedure in Table 5-17. If present, check signals S0, S180, S90, and S270 according to para. 5.11.6. If these signals are not present, check signals DE, DEEE (para 5.11.5) and signal KV. If these are present at the input of the S board, the S board is faulty. If not present, check the D board outputs (para. 5.11.5); then, if necessary, perform the procedure in Table 5-17, to isolate the fault to the D board or the boards preceding the D board in the signal flow path. (See Figure 6-3.)
5	Using the mode switch TEST positions, observe that E-board lamps DS7 (1I gate) and DS8 (2I gate) light to indicate the gates are passing clock signals to the counters. (Also verify at E-TP12 and E-TP13 if desired.)	Check that clock signals EICLK and ERCLK at 1I52E and 2I111E, respectively, are present during a TEST. If not, check wiring and connections. If present, there is a possibility that signals PRR and PIR are not present. Check these according to step 3, "Signal Not Present." Check wiring and connections if these signals are present at P board. If all these signals are present, check the counter outputs. Refer to Figures 6-9 to 6-12. One way to check the outputs is to allow the counters to count to 19999. If the mode switch is held to positions 1 and 3 while the 1683 is in a fixed range (1-9), the counter should count to 19999, if operating properly. Check that the BCD 8 and 1 (8 + 1 =9) outputs (see Figure 6-11) are "1", and that the 4 and 2 outputs are "0". Start with the "units" decade. If the signals are not present, the counter board must be faulty. If the signals are present there must be a poor board connection, since at least one of the signals should reach the displays. Trace signals through the Z board to the H board if necessary.	Use the mode switch TEST positions and check that a clock signal is present at the P board output. Use E-TP3 or, even better, use E28C. If the clock signal is present, check that signal PRIG at P-TP5 is a "1" when the mode switch is set to the TEST position. If present, proceed to step 6. If not present, check at P-TP1 that the level goes to "1" when the mode switch is set to TEST or TRACKING. If not, check the mode switch and wiring (Fig. 6-27). If P-TP1 goes to "1", the P board must be faulty. Before replacing the board, however, check that signal SVCO is present at P29E in the SINGLE MEAS mode. If TP1 does not go to "1", check that signals ZT1-ZT5 are all "1" when ***not*** in TEST or TRACKING modes. NOTE $\overline{PRIG}$ (E16E) is connected to Q-board STOP input and N-board INHIBIT input. Check circuits if boards are installed in 1683.
6	Check that signal $\overline{ECHANGE}$ at E-TP8 is a "1" in the fixed-range mode.	Check that main-gate input signals 1I$\overline{9F}$, 1I$\overline{0R}$ or 2I$\overline{9F}$ and 2I$\overline{OR}$ (as applicable) are "1" if the display ***does not*** read 19999 and counting forward and all zeros are counting in the reverse direction. Verify with the mode switch TEST positions, in the fixed-range mode. When the control is set to count down to 00000, the signal I$\overline{0R}$ should go to "0" when this count is reached. Then, when the switch is set to count forward, the signal(s) should go to "1". Similarly, the signal $\overline{9F}$ goes to "0" when the count reaches 19999 and to "1" when the control is then set for a reverse count (i.e., 19999 down to 00000). If these signals are not present at the P board, check that they are at the counter (I) boards (see note). If they are, replace the P board. If the signals are at the P board, check that signal $\overline{PLEAKOFF}$ (E79E) is "0" and signals $\overline{PIG}$ (E68E) and $\overline{PRG}$ (E72E) are "1" when the applicable gate is enabled with the mode switch TEST position (TEST 1 and 2, $\overline{PIG}$; TEST 3 and 4, $\overline{PRG}$). If these signals are present and the gates do not operate, replace the E board.	E-board range delay circuit is faulty; the "0" $\overline{ECHANGE}$ signal prevents the main gates from operating. NOTE 1I$\overline{9F}$ is at E-TP1 1I$\overline{0R}$ is at E-TP2 2I$\overline{9F}$ is at E-TP4 2I$\overline{0R}$ is at E-TP3 RANGE lamp lights when the counter is 19999 and forward or 00000 and reverse for both displays. This indicates that the counters are producing the proper range change signals.

Table 5-17 (Cont)
TROUBLESHOOTING – D BOARD
OR PRECEDING BOARD(S)
FAULTY

Step	Signal Check	Measurement Terminal	Signal Present	Signal Not Present
7	Signals at standards. (Refer to Figures 6-6 and 5-1.)	Check signal path through mother board for signals YC (CsD measurement only), KM, and BM. Figure 6-16 lists the states of the switching signals (ZS2, ZS3) for each measurement function and the state of each relay for each measurement. To energize a relay, the voltage at the base of a transistor should be 0.6 V.	———	Replace the defective part(s) that block the signal. (Refer to the mother board parts list.) Make sure other parts in the signal path are not defective.

Table 5-18
TROUBLESHOOTING – NO REBALANCE IN VMR MODE

Step	Procedure	Signal Present	Signal Not Present
1	Check that pulses are present at P-TP4 after the bridge balances. (Initiate another balance with START switch).	Proceed to Step 3. NOTE Check that no range change is required	Proceed to Step 2.
2	Set the mode switch to either TEST or TRACK and observe that pulses are present.	Check that signal ZVAR (P22C) goes to "0" when mode switch is set to VARIABLE MEAS RATE. If not, check wiring and switch. If it goes to "0", proceed to Step 3.	Check that signal $\overline{\text{NTNH}}$ is "1" (P15E). If not, trace the signal to locate the fault. If a "1", the PVMR generator must be faulty.
3	Check signal $\overline{\text{ECHANGE}}$ (P6C) is "1".	Proceed to Step 4 NOTE If signals $\overline{\text{ECHANGE}}$ or EBAL stay "0", the balance flip-flop will not reset and turn on the PVMR generator, to producing a start pulse in the PVMR mode.	Check wiring and E board. If not connections, E board must be faulty.
4	Check signal EBAL (P7C) is "1" at balance.	Portion of output of PVMR generator or input to start circuit on E board faulty.	Check that there is no up-range indication at the E board (E-DS1 not lit). If there is and no range change is required, the E board or counter(s) must be faulty. Check that signal EBAL (E95C) is a "1". If not, check interface with S board and S-board interface with circuit board (R-board, Figure 6-21) mounted on the bottom of the mother board. Para. 4.4.9 describes the operation of this circuit board.

Table 5-19
TROUBLESHOOTING — DISPLAYS COUNT
BUT DO NOT CHANGE RANGE
IN AUTOMATIC MODE

Step	Procedure	Signal Present	Signal Not Present
1	Observe lamps DS1 and DS2 on the E board. Perform the ranging check in para. 5.4.4 and note that lamp DS1 lights when the instrument up-ranges and that DS2 lights when it down-ranges.	If the lamps light, all the range-change signals are present to initiate a change of range. Put the instrument in AUTO range and refer to the ranging procedure in paragraph 5.4.4. Starting at the lowest range, range through all the ranges and observe that the E-board range counter BCD lamps (Figure 5-6) light to indicate each range. For example DS3 — indicates range 1 DS5 — range 2 DS5 & 3 — range 3 DS4 — range 4 DS4 & 3 — range 5, etc. If the lamps light, check signals $Z\overline{RNG1}$ - $Z\overline{RNG9}$ through the Z and H boards. Signals should go to "0" at output of E board decoders for corresponding range. If these lamps do not light, the E-board range delay, counter clock, and/or range counter must be faulty. If it is desired to isolate the fault to the board circuit, start at E-TP5 then go to TP7, and TP14. Figure 4-43 shows a timing diagram for these circuits. NOTE If the range up-ranges or down-ranges only to a certain range, the range counter has probably failed. If only certain intermediate ranges are not obtained, an IC in the Z-board range matrix has probably failed (Figure 6-27).	If the lamps do not light, this indicates that the proper range-change signals may not be received by E board, or that the RANGE AUTO switch and/or the associated auto-ranging circuitry on the E board may be faulty. Using the mode switch TEST positions and the fixed range mode (1-9), check the following signals go to "0" when the displays read as follows, as appropriate for up-range or down 1! (I) Display — Signal — Terminal 19999 and forward — $1\overline{I9F}$ — E-TP1 00000 and reverse — $1\overline{I0R}$ — E-TP2 2! (R) Display 19999 and forward — $2\overline{I9F}$ — E-TP4 00000 and reverse — $2\overline{I0R}$ — E-TP3 When any one of these signals is produced, the RANGE lamp should light. If it does, this will verify that the counters are producing the proper signals. Check that signals 1I00 (E80C) and 2I00 (E79C) go to "1" when its associated display reads 00XXX (any numbers in first three digits). If not present, check these outputs from the counter and replace the counters if necessary. Also check that signal $Y\overline{DOWN}$ (E97C) is a "1" during a TEST. If not, check for a short circuit. If the signal is not present at the Y board, the board is faulty. If all the signals are present, check that signal ERRNG (E115C) goes to "1" when the RANGE switch is set to AUTO. If not, the E-board mode circuit is faulty. If a "1", check at E113E to see if terminal goes to "1" when switch is set to AUTO. If not, the mode circuit is faulty.

Table 5-20
TROUBLESHOOTING — BALANCE IS SLOW

Step	Procedure	Signal Present	Signal Not Present
1	This type of fault indicates that the anticipator generator may not be functioning properly or that the S-board phase reference signals may be out of phase. First check that signal $P\overline{START}$, a 15-ms "0" level signal, is present at P43C at the start of a balance operation (LEAKAGE control set to OFF). This type of fault also indicates that the circuit mounted on the board at the bottom of the mother board may be faulty, holding the clock at a slow rate. Refer to Figure 6-21. Check the signal $P\overline{START}$ resets the flip-flop on that board at the start of a measurement. Also refer to para. 5.11.7.	Check that signal PAB (P34E) goes from "1" to "0" at the end of the 15-ms pulse, and that signal PAR (P33E) goes from "0" to "1". This will occur only for a short time during a balance. Signal PAR will then go back to "0" and PAB will go alternately to "0" and "1" during a balance operation. Refer to the table in Fig. 6-19 NOTE P-board lamps DS9 (PAB) and DS10 (PAR) can be observed for proper circuit operation. The lamps light when the signals are "1". If the signals are present, check the anticipator according to para. 5.11.5, part 2, first ensuring that the signals are received at the D board. Replace the D board if necessary. If the signals are not present at the D board, the P board is probably not functioning properly. If the D board is functioning properly, check the phase reference signals at the S board according to paragraph 5.11.6. If none of the above procedures isolate the fault, check that the SVCO clock output of the S-board varies according to the table on Fig. 6-22. If not, replace the S board. (The clock probably has failed, producing only a low-frequency clock.) Also see Table 5-10.	P-board "Start" circuitry interface faulty or circuit board at bottom of mother board faulty. Refer to para. 4.4.9 for a description of how this circuit operates, if necessary.

Table 5-21
TROUBLESHOOTING – NO LEAKAGE-CURRENT MEASUREMENT

Step	Procedure	Signal Present	Signal Not Presemt
1	Set the 1683 for a very long measurement and set the LEAKAGE controls for some current (1 μA). Initiate a measurement and check that signal LNG goes to "0" some time during the measurement.	GO lamp, interface wiring, or Z-board leakage-current circuitry (Fig. 6-28) faulty.	Proceed to step 2. NOTE The timing diagram on Figure 6-15 illustrates circuit operation when measuring external leakage current.
2	Check that when a measurement is initiated that signal $\overline{PSTL}$ (P15C or P-TP8) goes to "0" for about 20 ms.	Proceed to Step 2.	P-board start circuit or anti-bounce switch may be faulty. If the start was initiated at the front panel or by a test fixture, the fault can be isolated to the anti-bounce switch by grounding $\overline{OSING1}$ (P9E) or LNG (P23C) and observing the signal $\overline{PSTL}$ occurs. (See Fig. 6-18.) Before replacing the P board, check that the start signal(s) are present at the input to the board. Check that the following start signals, as applicable, go to "0" when the start is initiated. Front panel or Test Fixture, $\overline{ZSTART}$ (P2E) Via N board, $\overline{NSING2}$ (P3E) Via Q board, $\overline{OSING1}$ (P9E) $\overline{NSING2}$ must be > 20 ms $\overline{NSING1}$ must be "0" > 0.5 μs < 50 ms If the signals are present, the P board is faulty. If not present, trace the signals, to find the fault.
3	Check that signal $\overline{PLEAKOFF}$ (P5C) goes to "0" when a measurement is initiated.	Check that the following signals are present at the inputs to the indicated boards at the start of a leakage-current measurement. $\overline{PLEAKOFF}$ goes to "0" at Y4E, 4C T6E L24F E79E $\overline{PSTL}$ goes to "0" at L8E $\overline{PLEAK}$ goes to "0" at L4E. Check interfaces if signals not present. If $\overline{PLEAK}$ is not present, part of the P board (gate at output of IC28) may have failed. If signals are present, proceed to step 4.	Check that signal ZLEAKOFF (P5E) is a "1". If not, check wiring and LEAKAGE switch (Fig. 6-28) If present, check that signal ZS2 (P6E) is a "0". If not, check function switch (Fig. 6 27) and associated circuitry and wiring. If the proper signals are present, flip-flop P-IC28 and/or its associated circuitry is probably faulty.
4	Check during a measurement that there is no voltage at Y4E, 4C (signal YC) during a leakage-current measurement. The instrument should be in some fixed range.	One or more relays on the Y board have not been disabled by signal $\overline{PLEAKOFF}$. NOTE If displays count during a leakage-current measurement, check that the oscillator (T board) and main gates (E board) are shut off by $\overline{PLEAKOFF}$.	Y-board relays disabled by $\overline{PLEAKOFF}$. Proceed to Step 5.
5	Check that a signal level is present at L9E at the start of a measurement.	L board faulty. Refer to paragraph 5.11.8 for details on checking the board operation. Replace the board if necessary.	Check connections.

Parts Lists and Diagrams—Section 6

General 6-1
Mechanical Parts 6-3
Signal Index 6-5
Federal Manufacturer's Code 6-7
Detailed Block Diagram 6-7
Signal Functional Flow Diagram 6-9
Schematics and Parts Lists
B-Divider, B 6-11
C-Divider, C 6-13
Detector, D 6-15
Range, E 6-17
F-Display Module, F 6-18
G-Display Module, G 6-18
U-Display Module, U 6-18
Display, H 6-19, 6-20
Counters, 1I and 2I 6-21, 6-33
Power Amplifier, J 6-25
K-Divider, K 6-27
Leakage-Current, L 6-29
Mother, M 6-31
Data Output, N 6-33
Program, P 6-35, 6-37
Auxiliary (Data-Input), Q 6-39
Auxiliary Comparator, R 6-40
Reference, S 6-41
Oscillator, T 6-43
Power Supply, V 6-45
Y-Bridge, Y 6-47
Control, Z 6-49, 6-50
1683-P1 Test Fixture (including mechanical parts) 6-50
Switch Diagram 6-51
GR Type 874®
Coaxial Connectors 6-52

6.1 GENERAL.

The schematic and logic diagrams are included in the order of their letter designation (Table 4-1), to allow easy location of the drawing. The letter designation is at the end of the figure caption, and it corresponds to the identification of the circuits in the block diagram, functional flow diagram, designations on the circuit-board latches that identify the boards in the instrument, and signal designations in the Signal Run List.

The F, G, and U module schematics are on the H-board schematic, and the assembly layouts are located preceding the H-board schematic. Figure 6-11 shows the interface between the counters and the display circuits.

The heavy lines on drawings denote the major signal flow in the circuits and the instrument.

Reference designation usage is described in paragraph 5.7.

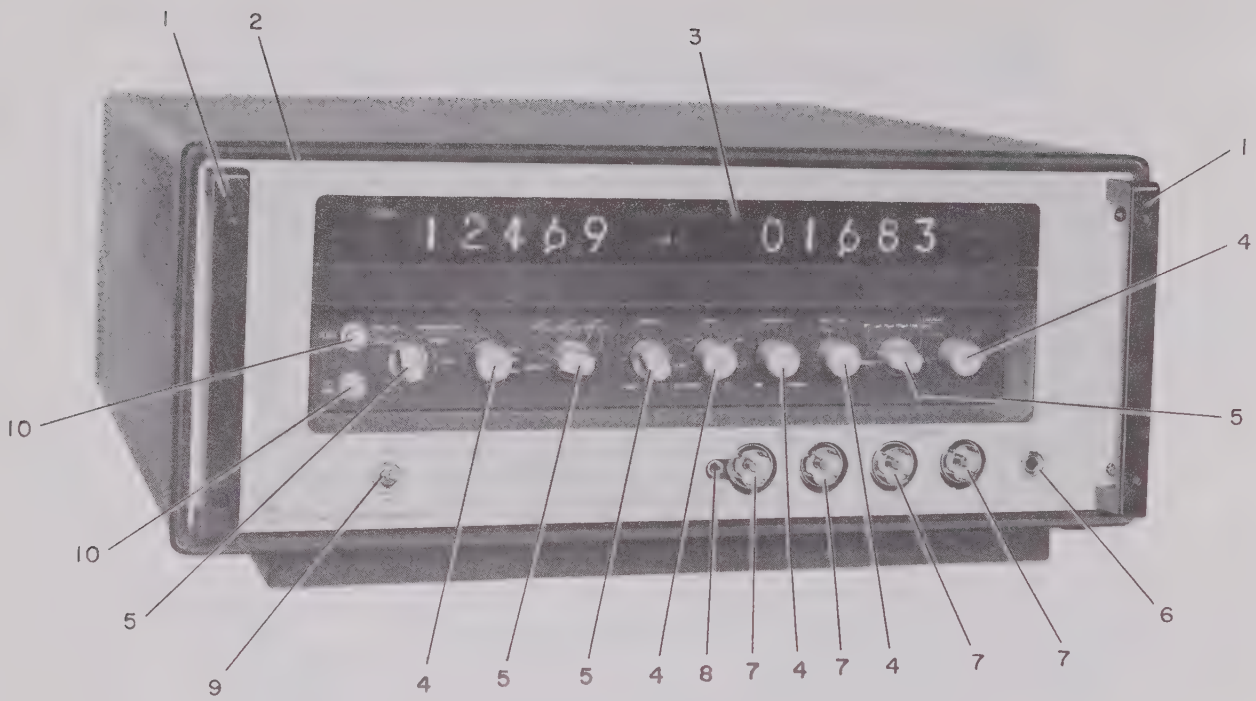


Figure 6-1. Front-panel view identifying parts.

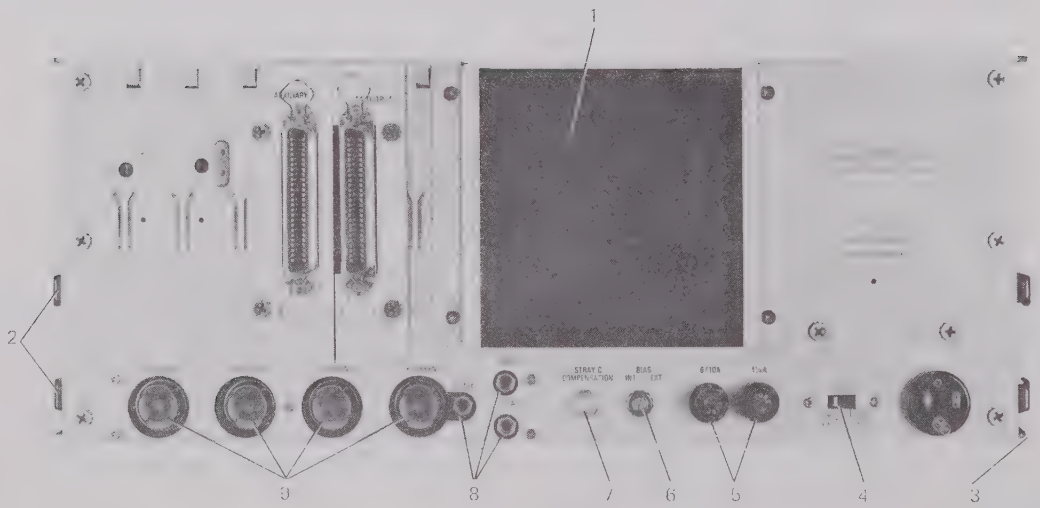


Figure 6-2. Rear-panel view identifying parts.

MECHANICAL PARTS LIST

Qty	Fig Ref	Description	GR Part No.	Mfg Code	Mfg Part No.	Fed Stock No.
FRONT PANEL						
2	1	Handle	5360-2017	24655	5360-2017	
1	2	Cabinet gasket	5331-2182	24655	5331-2182	
1	3	Polaroid window	1683-7000	24655	1683-7000	
5	4	Knob asm., LEAKAGE, level selector; OSC LEVEL; SENSITIVITY; BIAS; FAST/STOP/SLOW, including retainer 5220-5402	5520-5221	24655	5520-5221	
4	5	Knob asm, LEAKAGE, μA-mA; RANGE; FUNCTION SELECTOR; MODE, including retainer 5220-5402	5500-5221	24655	5500-5221	
1	6	Signal jack, A-J56, EXT START	4260-1050	82389	112B	
4	7	Coaxial connector, POTENTIAL (+, -), CURRENT (+, -)	0874-9461	24655	0874-9461	
1	8	Panel jack, A-S53, GUARD	1683-6000	24655	1683-6000	
1	9	Switch, A-S59, POWER-OFF	7910-1300	04009	83053-SA	5930-909-3510
2	10	Pushbutton switch, A-S2, START; A-S3, SET ZERO	7870-1511	81073	4001 N.O.	
MISCELLANEOUS						
1		Bench cabinet asm.:	4173-4004	24655	4173-4004	
1		Base tilt	4171-1077	24655	4171-1077	
1		Foot asm.	4171-1012	24655	4171-1012	
1		Indicator asm:	1683-2000	24655	1683-2000	
1		Window, Capacitor-Inductor Ranges	1683-7411	24655	1683-7411	
14		Lamp, DS5-DS16	5600-1070	17460	2334	
1		Indicator asm:	1683-2010	24655	1683-2010	
1		Window, Resistor-Loss Ranges	1683-7421	24655	1683-7421	
9		Lamp, DS17-DS23	5600-1070	17460	2334	
1		Indicator asm:	1683-2020	24655	1683-2020	
1		Window, Measurement Frequency	1683-7431	24655	1683-7431	
4		Lamp, DS1-DS4	5600-1070	17460	2334	
REAR PANEL						
1	1	Filter	5270-4509	24655	5270-4509	
8	2	Slide blocks	4171-7050	24655		
1	3	Power plug, A-J54	4240-0210	24655	4240-0210	
1	4	Slide switch, A-S51, LINE VOLTAGE SELECTOR	7910-0831	42190	4603	
2	5	Fuse mounting device	5650-0100	71400	HKP-H	5920-284-7144
1	6	Switch, A-S52, BIAS - INT/EXT	7270-4910	24655	7270-4910	
1	7	BNC connector, A-J55, STRAY C COMPENSATION	4230-2301	09408	UG-1094 A/U	
3	8	Panel jack, A-J52, + BIAS; A-J51, -BIAS; A-J50, GUARD	1683-6000	24655	1683-6000	
4	9	Coaxial connector, +POTENTIAL, -POTENTIAL, +CURRENT, -CURRENT	0874-4552	24655	0874-4552	
MISCELLANEOUS						
1		Cover plate - when option 5a or 5b is not utilized*	1683-8730	24655	1683-8730	
1		Cover plate - when option 2 only is not utilized*	1683-8740	24655	1683-8740	

*NOTE: Option 2 is remote programmability
Option 5a is low-level data output
Option 5b is high-level data output

NOTE

Figure 6-24 shows most of these parts. Also refer to the figures in Section 5.

ELECTRICAL PARTS LIST

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
	TRANSFORMER ASSEMBLY AND CHASSIS PANEL ELECTRICAL REPLACEABLE PARTS.				
	CAPACITORS*				
C50 and C51	Electrolytic, 10,000 μF +75-10%	4450-6211	37942	TT, 10,000 μF +75-10%	
C52	Electrolytic, 21,000 μF +75-10%	4450-6210	37942	TT, 21,000 μF +75-10%	
C53	Electrolytic, 2400/1200/1200 μF	4450-4200	37942	20-21339-99-6	
C54	Electrolytic, 50/25/25 μF	4450-0800	56289	D28936	5910-970-1589
C60	Tantalum, 47 μF ±20%	4450-5614	56289	150D476X0020R2	
	CIRCUIT BREAKER*				
CB1	Circuit breaker	1926-2000	24655	1926-2000	
	CONNECTORS*				
J54	Power Plug	4240-0210	24655	4240-0210	
J55	Multiple Socket	4230-2301	09408	UG-1094A/U	
J56	Signal jack	4260-1050	82389	112B	
	DIODES*				
CR50 thru CR53	Type IN4140	6081-1014	13327	IN4140	
CR54 and CR55	Type IN1613	6081-1012	24446	IN1613	5961-764-3184
CR56 and CR57	Type IN4140	6081-1014	13327	IN4140	
CR58 thru CR61	Type IN3254	6081-1002	09213	IN3254	5961-082-3988
	FUSES*				
F50	Slo-blo, 1.25 A	5330/1600	71400	AGC, 1.25 Amp.	5920-280-3173
F51	Slo-blo, 0.6 A	5330-1100	71400	MDL, 0.6 Amp.	5920-976-1586
	RESISTORS*				
R1	Pot., comp., 1 MΩ ±10%	6045-5100	01121	JS, 1 MΩ 20%	
R2	Pot., comp., 250 Ω ±10%	6045-0250	01121	JT, 250 Ω 10%	
R3	Pot., comp., 5 kΩ ±10%	6045-0230	01121	JT, 5 kΩ 10%	
R4	Pot., 1 kΩ ±10%	6000-0300	01121	JU, 1 kΩ 10%	5905-644-6789
R5	Potentiometer	0971-9710	24655	0971-9710	
R50	Low-power, wire wound, REW-3C, 1 Ω ±10%	6760-9109	75042	BWH, 1 Ω 10%	
R51	Comp., 75 Ω ±5%	6100-0755	01121	RC20GF750J	5905-279-1758
R52	Comp., 220 Ω ±5%	6110-1225	01121	RC32GF221J	5905-279-2053
R53	Comp., 24 Ω ±5%	6100-0245	01121	RC20GF240J	5905-279-1750
R54	Comp., 270 kΩ ±5%	6100-4275	01121	RC20GF274J	5905-190-8865
R55 and R56	Low power, wire wound 0.39 Ω ±5%	6760-8395	75042	BWH, 0.39 Ω 5%	
	SWITCHES*				
S2 and S3	Push button	7870-1511	81073	4001 N.O.	
S4	Rotary wafer	7890-5298	24655	7890-5298	
S5	Rotary wafer	7890-5299	24655	7890-5299	
S6	Rotary wafer	7890-5297	24655	7890-5297	
S9	Rotary wafer	7890-5301	24655	7890-5301	
S50	Slide	7910-1300	04009	83053-SA	
S51	Slide	7910-0831	42190	4603	
S52	Rotary wafer	7890-5327	24655	7890-5327	
	TRANSISTORS*				
Q50	Type 40251	8210-1097	12672	40251	
Q51	Type 2N3740	8210-1121	93916	2N3740	
Q52	Type 40250	8210-1095	12672	40250	
Q53	Type 40251	8210-1097	12672	40251	

*All parts listed are preceeded by the designation A-, on drawings and schematics.

6.2 SIGNAL LIST.

The following table lists all ths signals used in the 1683. The "Signal Name and Description" listing lists the signal names and describes the acronym term and, generally, the function of signal. The first letter of the signal name indicates the circuit board from which the signal originates.

The QOSCOFF signal, for example, originates or is routed from the Q board. OSCOFF means that this signal turns off the bridge oscillator. A signal with a prime mark following it, such as ECHANGE', indicates a bar over the signal name, e.g. $\overline{\text{ECHANGE}}$, which indicates that the desired signal is a logical "0" level.

Most of the signal connections are at etched-circuit-board socket-pin connections available at the bottom of the instrument on the mother board. The letters E and C shown with pin designations on the schematics designate the side of the board the signals are fed to or are forwarded from — the etched side (E) or component side (C). The mother board has two rows of pin connections, one for the etched-side signals and one for the component-side connections of each board.

Other signal connections are at anchor terminals (AT's) at various points in the instrument; the counter-clockwise position (CCW), clockwise (CW), arms (ARM) positions of potentiometers; and switch connections (for example, AS7-2). The following examples illustrate the designation system:

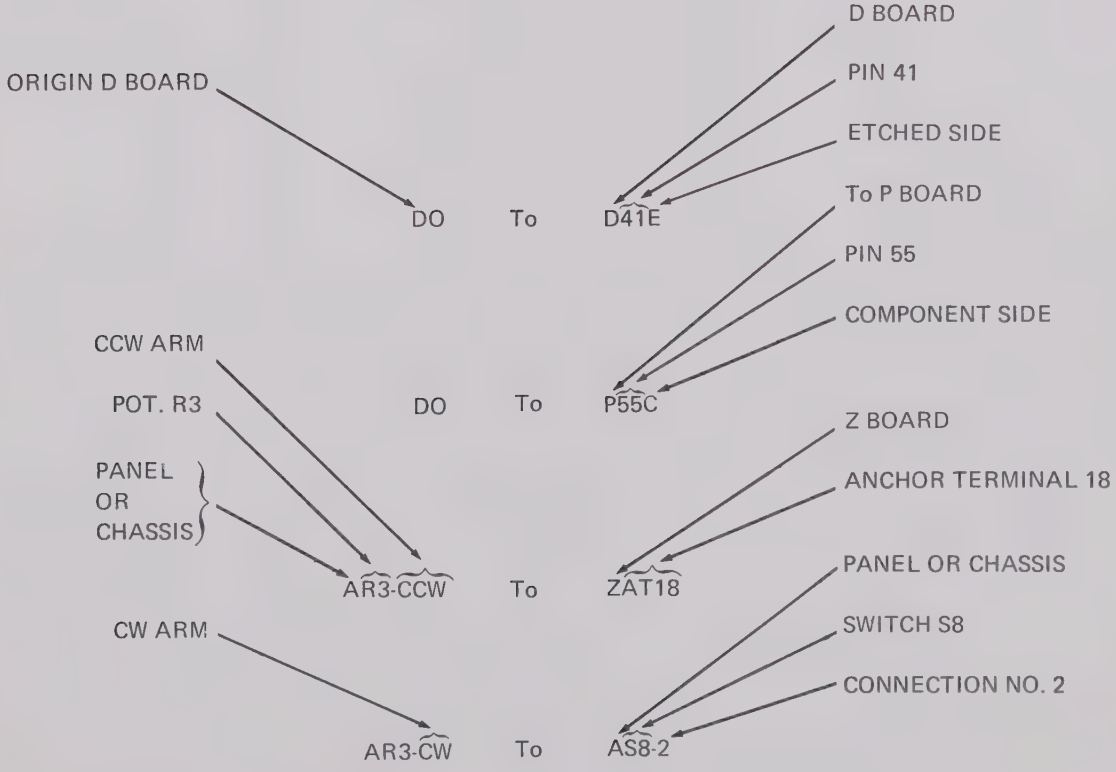


Table 6
SIGNAL LIST

SIGNAL DESCRIPTIONS

BM	OUTPUT OF B DIVIDER
CC	OUTPUT OF C DIVIDER
DE	OUTPUT OF FILTER
DEEE	EARLY ERROR SIGNAL
DD	"SQUARED" ERROR SIGNAL
EBAL	BALANCE SIGNAL
ECHANGE	RANGE CHANGE SIGNAL
ERAN	RANGE LIGHT
ERRNG	REMOTE RANGING
E1ICLK	I SIDE CLOCK
E2ICLK	R SIDE CLOCK
I1Q0	I COUNTER TEN-THOUSANDS 1
I1Q1	I COUNTER THOUSANDS 8
I1Q2	I COUNTER THOUSANDS 4
I1Q3	I COUNTER THOUSANDS 2
I1Q4	I COUNTER THOUSANDS 1
I1Q5	I COUNTER HUNDREDS 8
I1Q6	I COUNTER HUNDREDS 4
I1Q7	I COUNTER HUNDREDS 2
I1Q8	I COUNTER HUNDREDS 1
I1Q9	I COUNTER TENS 8
I1Q10	I COUNTER TENS 4
I1Q11	I COUNTER TENS 2
I1Q12	I COUNTER TENS 1
I1Q13	I COUNTER UNITS 8
I1Q14	I COUNTER UNITS 4
I1Q15	I COUNTER UNITS 2
I1Q16	I COUNTER UNITS 1
I1Q0	I COUNTER 00XXX
I1OR	I COUNTER 00000-REVERSE
I19F	I COUNTER 19999-FORWARD
R1Q0	R COUNTER TEN-THOUSANDS 1
R1Q1	R COUNTER THOUSANDS 8
R1Q2	R COUNTER THOUSANDS 4
R1Q3	R COUNTER THOUSANDS 2
R1Q4	R COUNTER THOUSANDS 1
R1Q5	R COUNTER HUNDREDS 8
R1Q6	R COUNTER HUNDREDS 4
R1Q7	R COUNTER HUNDREDS 2
R1Q8	R COUNTER HUNDREDS 1
R1Q9	R COUNTER TENS 8
R1Q10	R COUNTER TENS 4
R1Q11	R COUNTER TENS 2
R1Q12	R COUNTER TENS 1
R1Q13	R COUNTER UNITS 8
R1Q14	R COUNTER UNITS 4
R1Q15	R COUNTER UNITS 2
R1Q16	R COUNTER UNITS 1
R1Q0	R COUNTER 00XXX
R1OR	R COUNTER 00000-REVERSE
R19F	R COUNTER 19999-FORWARD
JHC	OUTPUT OF POWER AMPLIFIER
JTOSC	STRAY CAPACITANCE SIGNAL
KM	OUTPUT OF K DIVIDER
KS0	DIVIDER TEN-THOUSANDS 1
KS1	DIVIDER THOUSANDS 8
KS2	DIVIDER THOUSANDS 4
KS3	DIVIDER THOUSANDS 2
KS4	DIVIDER THOUSANDS 1
KS5	DIVIDER HUNDREDS 8
KS6	DIVIDER HUNDREDS 4
KS7	DIVIDER HUNDREDS 2
KS8	DIVIDER HUNDREDS 1
KS9	DIVIDER TENS 8
KS10	DIVIDER TENS 4
KS11	DIVIDER TENS 2
KS12	DIVIDER TENS 1
KS13	DIVIDER UNITS 8
KS14	DIVIDER UNITS 4
KS15	DIVIDER UNITS 2
KS16	DIVIDER UNITS 1
KV	PHASE REFERENCE SIGNAL
LEAKOUT	OUTPUT OF LEAKAGE AMPLIFIER
LGO	LEAKAGE GO
LNG	LEAKAGE NO-GO
MD	ERROR SIGNAL
NINH	INHIBIT REBALANCE
NSING2	SINGLE START PULSE
PAB	ANTICIPATOR DECAY SIGNAL
PABORT	ABORT MEASUREMENT SIGNAL
PAR	ANTICIPATOR RISE SIGNAL
PBUSY	BRIDGE IS BALANCING
PCLK12	CLOCK PULSE TIME 1-2
PCLK23	CLOCK PULSE TIME 2-3
PIG	CLOCK OFF I SIDE
PIR	REVERSE ON I SIDE
PLEAK	START LEAKAGE MEASUREMENT
PLKOFF	GATE OFF LEAKAGE MODE
PRG	CLOCK OFF R SIDE
PRIG	CLOCKS ENABLED
PRR	REVERSE ON R SIDE
PSTART	START PULSE
PSTL	START LEAKAGE PULSE
PVMR	VARIABLE MEASUREMENT CLOCK
QBIAS	BIAS CONTROL GATE
QCD	MEASURE CS WITH D
QCR	MEASURE CS WITH ESR
QLEAK	LEAKAGE LIMIT
QLR	MEASURE LS WITH RS
QRAUTOXT	AUTO RANGE EXTERNAL
QSETO	SET ZERO EXTERNAL
QSING1	START PULSE
Q1000	MEASURE AT 1000HZ
SBAL	BALANCE SIGNAL
SENS	SENSITIVITY LEVEL
SFAST	BRIDGE BALANCING AT FASTEST RATE
SUNBAL	ERROR LESS THAN 8 COUNTS
SVCO	CLOCK OSCILLATOR
S0	0-DEGREE PHASE REFERENCE
S90	90-DEGREE PHASE REFERENCE
S180	180-DEGREE PHASE REFERENCE
S270	270-DEGREE PHASE REFERENCE
TOSC	OUTPUT OF OSCILLATOR
VSYNC	120-HZ SYNC
XLC	LOW CURRENT TERMINAL
XLV	LOW VOLTAGE TERMINAL
XHV	HIGH VOLTAGE TERMINAL
YC	OUTPUT OF RA AMPLIFIER
YDOWN	RA IS SATURATED
YV	OUTPUT OF DIFFERENTIAL AMPLIFIER
ZI3	XX.XXX I SIDE
ZI4	XXX.XX I SIDE
ZI5	XXXX.X I SIDE
ZLEAK	LEAKAGE LEVEL
ZLEAK1	LEAKAGE RANGE 1-MICROAMP
ZLEAK2	LEAKAGE RANGE 10-MICROAMPS
ZLEAK3	LEAKAGE RANGE 100-MICROAMPS
ZLEAK4	LEAKAGE RANGE 1-MILLIAMP
ZLEAK5	LEAKAGE RANGE 10-MILLIAMPS
ZLGO	GO LIGHT
ZLKOFF	GATE OFF LEAKAGE MODE
ZLNG	NO-GO LIGHT
ZL0	1000 HZ LIGHT
ZL1	120 HZ LIGHT
ZL2	D LIGHT
ZL3	KILOHMS LIGHT
ZL4	OHMS LIGHT
ZL5	MILLIOHMS LIGHT
ZL6	MICROHENRIES LIGHT
ZL7	MILLIHENRY
ZL7	MILLIHENRIES LIGHT
ZL8	HENRIES LIGHT
ZL9	NANOHENRIES LIGHT
ZL10	MILLIFARADS LIGHT
ZL11	MICROFARADS LIGHT
ZL12	NANOFARADS LIGHT
ZL13	PICOFARADS LIGHT
ZRAN	RANGE LIGHT
ZRAUTO	AUTO RANGE REMOTE
ZRFN	FUNCTION REMOTE
ZRLEAK	LEAKAGE REMOTE
ZRMOD	MODE REMOTE
ZRNG1	RANGE 1
ZRNG2	RANGE 2
ZRNG3	RANGE 3
ZRNG4	RANGE 4
ZRNG5	RANGE 5
ZRNG6	RANGE 6
ZRNG7	RANGE 7
ZRNG8	RANGE 8
ZRNG9	RANGE 9
ZR2	X.XXXX R SIDE
ZR3	XX.XXX R SIDE
ZR4	XXX.XX R SIDE
ZR5	XXXX.X R SIDE
ZRRNG	RANGE REMOTE
ZSENS	SENSITIVITY LEVEL
ZSETO	SET ZERO
ZSING	SINGLE MEASUREMENT MODE
ZSTART	START PULSE
ZS2	INDUCTANCE
ZS3	1000HZ
ZS3D	120OHZ
ZTBIAS	BIAS LEVEL
ZTOSC	OSCILLATOR LEVEL
ZTRACK	TRACKING MODE
ZT1	COUNT I SIDE FORWARD
ZT2	COUNT I SIDE REVERSE
ZT3	COUNT R SIDE FORWARD
ZT4	COUNT R SIDE REVERSE
ZUNBAL	UNBALANCED LIGHT
ZVAR	VARIABLE MEASUREMENT MODE
ZVAR2	VARIABLE MEASUREMENT RATE CONTROL

FEDERAL MANUFACTURER'S CODE

From Federal Supply Code for Manufacturers Cataloging Handbooks H4-1 (Name to Code) and H4-2 (Code to Name) as supplemented through August, 1968.

Code	Manufacturer
00192	Jones Mfg. Co, Chicago, Illinois
00194	Welsco Electronics Corp, L.A., Calif.
00434	Schweber Electronics, Westburg, L.I., N.Y.
00656	Aerovox Corp, New Bedford, Mass
01009	Alden Products Co, Brockton, Mass
01121	Allen-Bradley, Co, Milwaukee, Wisc.
01236	Leeds Radio Company, N.Y.
01255	Litton Industries Inc, Beverly Hills, Calif
01295	Texas Instruments, Inc, Dallas, Texas
02114	Ferroxcube Corp, Saugerties, N.Y. 12477
02606	Fenwal Lab Inc, Morton Grove, Ill.
02660	Amphunol Electron Corp, Broadview, Ill.
02768	Fastex, Des Plaines, Ill 60016
03042	Carter Ink Co., Camb. Mass. 02142
03508	G.E. Semicon Prod, Syracuse, N.Y. 13201
03636	Grayburne, Yonkers, N.Y. 10701
03888	Pyrofilm Resistor Co, Cedar Knolls, N.J.
03911	Clairex Corp, New York, N.Y. 10001
04009	Arrow-Hart & Hegeman, Hart., Conn. 06106
04643	Digitronics Corp., Albertson, N.Y. 11507
04713	Motorola, Phoenix, Ariz 85008
05170	Engr'd Electronics, Santa Ana, Calif. 92702
05624	Barber-Colman Co, Rockford, Ill. 61101
05748	Barnes Mfg. Co., Mansfield, O. 44901
05820	Wakefield Eng, Inc, Wakefield, Mass 01880
06743	Clevite Corp., Cleveland, O. 44110
07126	Digitron Co, Pasadena, Calif
07127	Eagle Signal (E.W. Bliss Co.), Baraboo, Wisc
07261	Avnet Corp, Culver City, Calif 90230
07263	Fairchild Camera, Mountain View, Calif.
07387	Bertcher Corp, No. Los Angeles, Calif.
07595	Amer Semicond, Arlington Hts, Ill 60004
07828	Bodine Corp, Bridgeport, Conn. 06605
07829	Bodine Electric Co, Chicago, Ill. 60618
07910	Cont Device Corp, Hawthorne, Calif.
07983	State Labs Inc, N.Y., N.Y. 10003
07999	Borg Inst., Delavan, Wisc 53115
08730	Vemaline Prod Co., Franklin Lakes, N.J.
09213	G.E. Semiconductor, Buffalo, N.Y.
09408	Star-Tronics Inc, Georgetown, Mass 01830
09823	Burgess Battery Co, Freeport, Ill.
09922	Burndy Corp, Norwalk, Conn 06852
11236	C.T.S. of Berne, Inc, Berne, Ind. 46711
11599	Chandler Evans Corp, W. Hartford, Conn.
12040	National Semiconductor, Danbury, Conn.
12498	Crystalonics, Cambridge, Mass. 02140
12672	RCA, Woodbridge, N.J.
12697	Clarostat Mfg Co, Inc, Dover, N.H 03820
12954	Dickson Electronics, Scottsdale, Ariz.
13327	Solitron Devices, Tappen, N.Y. 10983
14433	ITT Semiconductors, W Palm Beach, Fla.
14655	Cornell-Dubilier Electric Co , Newark, N.J.
14674	Corning Glass Works, Corning, N.Y.
14936	General Instrument Corp, Hicksville, N.Y.
15116	Microdot Magnetics Inc, Los Angeles, Calif
15238	ITT, Semiconductor Div, Lawrence, Mass
15605	Cutler-Hammer Inc, Milwaukee, Wisc. 53233
16037	Spruce Pine Mica Co, Spruce Pine, N.C.
16636	Indiana General Corp, Oglesby, Ill. 61348
17701	Singer Co, Diehl Div, Somerville, N.J.
18736	Voltronics Corp, Hanover, N.J. 07936
19396	Illinois Tool Works, Paxton Div, Chicago, Ill.
19048	Computer Diode Corp, S. Fairlawn, N.J. 07410
19617	Cabtron Corp., Chicago, Ill. 60622
19644	LRC Electronics, Horseheads, N.Y.
19701	Electra Mfg Co, Independence, Kansas 67301
20754	KMC Semiconductor Corp., Long Valley, N.J. 07853
21335	Fafnir Bearing Co, New Briton, Conn.
22753	VID Electronics Corp, Hollywood, Fla.
23342	Avnet Electronics Corp, Franklin Park, Ill.
24446	G.E., Schenectady, N.Y. 12305
24454	G.E., Electronics Comp, Syracuse, N.Y.
24455	G.E. (Lamp Div.), Nela Park, Cleveland, Ohio
24655	General Radio Co, W. Concord, Mass. 01781
26806	American Zettlet Inc, Costa Mesa, Calif.
28520	Hayman Mfg Co, Kenilworth, N.J.
28959	Hoffman Electronics Corp, El Monte, Calif.
30646	Beckman Instruments Inc, Cedar Grove, N.J. 07009
30874	I.B.M., Armonk, New York
32001	Jensen Mfg. Co, Chicago, Ill. 60638
33173	G.E. Comp, Owensboro, Ky. 42301
34141	Koehler Mfg. Co. Inc., Marlboro, Mass. 01752
35929	Constants Co, Mont. 19, Que.
37942	P.R. Mallory & Co Inc, Indianapolis, Ind.
38443	Marlin-Rockwell Corp, Jamestown, N.Y.
40931	Honeywell Inc, Minneapolis, Minn. 55408
42190	Muter Co, Chicago, Ill. 60638
42498	National Co, Inc, Melrose, Mass 02176
43991	Norma-Hoffman, Stanford, Conn 06904
49671	RCA, New York, N.Y 10020
49956	Raytheon Mfg Co, Waltham, Mass 02154
53021	Sangamo Electric Co, Springfield, Ill 62705
54294	Shallcross Mfg Co, Selma, N.C.
54715	Shure Brothers, Inc, Evanston, Ill
56289	Sprague Electric Co, N. Adams, Mass
58730	Thomas and Betts Co, Elizabeth, N.J 07207
59875	TRW Inc, (Accessories Div), Cleveland, Ohio
60399	Torrington Mfg Co, Torrington, Conn
61637	Union Carbide Corp, New York, N.Y 10017
61864	United-Carr Fastener Corp, Boston, Mass
63060	Victoreen Instrument Co, Inc, Cleveland, O
63743	Ward Leonard Electric Co, Mt. Vernon, N.Y.
65083	Westinghouse (Lamp Div), Bloomfield, N.J
65092	Weston Instruments, Newark, N.J.
70485	Atlantic-India Rubber, Chicago, Ill. 60607
70563	Amperite Co, Union City, N.J. 07087
70903	Belden Mfg Co, Chicago, Ill 60644
71126	Bronson, Homer D, Co, Beacon Falls, Conn
71279	Cambridge Thermionic Corp, Camb Mass 02138
71294	Canfield, H.O. Co, Clifton Forge, Va 24422
71400	Bussman (McGraw Edison), St. Louis, Mo
71468	ITT Cannon Elec, L.A., Calif 90031
71590	Centralab, Inc, Milwaukee, Wisc. 53212
71666	Continental Carbon Co, Inc, New York, N.Y.
71729	Crescent Box Corp, E Phila, Penn. 19134
71707	Coto Coil Co Inc, Providence, R.I
71744	Chicago Miniature Lamp Works, Chicago, Ill
71785	Cinch Mfg Co, Chicago, Ill. 60624
71823	Darnell Corp, Ltd, Downey, Calif 90241
72136	Electro Motive Mfg Co, Wilmington, Conn
72259	Nytronics Inc, Berkeley Heights, N.J. 07922
72619	Dialight Co, Brooklyn, N.Y. 11237
72699	General Instr Corp, Newark, N.J. 07104
72765	Drake Mfg Co, Chicago, Ill 60656
72825	Hugh H. Eby Inc, Philadelphia, Penn 19144
72962	Elastic Stop Nut Corp, Union, N.J. 07083
72982	Erie Technological Products Inc, Erie, Penn.
73138	Beckman Inc, Fullerton, Calif 92634
73445	Amperex Electronics Co, Hicksville, N.Y.
73559	Carling Electric Co, W. Hartford, Conn.
73690	Elco Resistor Co, New York, N.Y.
73899	JFD Electronics Corp, Brooklyn, N.Y. 11219
74193	Heinemann Electric Co, Trenton, N.J.
74861	Industrial Condenser Corp, Chicago, Ill 60618
74868	Amphenol Corp, Danbury, Conn 06810
74970	E.F. Johnson Co, Waseca, Minn 56093
75042	IRC Inc, Philadelphia, Penn 19108
75382	Kulka Electric Corp, Mt Vernon, N.Y.
75491	Lafayette Industrial Electronics, Jamaica, N.Y
75608	Linden and Co, Providence, R.I
75915	Littelfuse, Inc, Des Plaines, Ill 60016
76005	Lord Mfg Co, Erie, Penn. 16512
76149	Mallory Electric Corp, Detroit, Mich. 48204
76487	James Millen Mfg. Co., Malden, Mass. 02148
76545	Mueller Electric Co., Cleveland, Ohio 44114
76684	National Tube Co, Pittsburg, Penn -
76854	Oak Mfg Co, Crystal Lake, Ill.
77147	Patton MacGuyer Co, Providence, R.I.
77166	Pass-Seymour, Syracuse, N.Y.
77263	Pierce Roberts Rubber Co, Trenton, N.J.
77329	Positive Lockwasher Co, Newark, N.J.
77342	American Machine & Foundry Co, Princton, Ind. 47570
77542	Ray-O-Vac Co, Madison, Wisc.
77630	TRW, Electronic Comp, Camden, N.J. 08103
77638	General Instruments Corp, Brooklyn, N.Y.
78189	Shakeproof (Ill. Took Works), Elgin, Ill 60120
78277	Sigma Instruments Inc, S Braintree, Mass.
78488	Stackpole Carbon Co, St. Marys, Penn.
78553	Tinnerman Products, Inc, Cleveland, Ohio
79089	RCA, Rec Tube & Semicond, Harrison, N.J.
79725	Wiremold Co, Hartford, Conn. 06110
79963	Zierick Mfg Co, New Rochelle, N.Y.
80009	Tektronix Inc, Beaverton, Ore. 97005
80030	Prestole Fastener, Toledo, Ohio
80048	Vickers Inc, St. Louis, Mo
80131	Electronic Industries Assoc, Washington, D.C.
80183	Sprague Products Co, No. Adams, Mass.
80211	Motorola Inc., Franklin Park, Ill. 60131
80258	Standard Oil Co, Lafeyette, Ind.
80294	Bourns Inc, Riverside, Calif 92506
80368	Sylvania Electric Products Inc, N.Y. 10017
80431	Air Filter Corp, Milwaukee, Wisc. 53218
80583	Hammarlund Co, Inc, New York, N.Y.
80740	Beckman Instruments, Inc, Fullerton, Calif.
80894	Pure Carbon Co., St Marys, Penn 15857
81030	International Instrument, Orange, Conn
81073	Grayhill Inc, LaGrange, Ill. 60525
81143	Isolantite Mfg Corp, Stirling, N.J 07980
81349	Military Specifications
81350	Joint Army-Navy Specifications
81386	Fenwal Electronics, Framingham, Mass 01701
81483	International Rectifier Corp, El Segundo, Calif 90245
81751	Columbus Electronics Corp, Yonkers, N.Y
81831	Filtron Co, Flushing, L.I., N.Y. 11354
81840	Ledex Inc, Dayton, Ohio 45402
81860	Berry-Wright Corp, Watertown, Mass.
82219	Sylvania Elec Prod, Emporium, Penn.
82273	Indiana Pattern & Model Works, LaPort, Ind
82389	Switchcraft Inc, Chicago, Ill 60630
82647	Metals & Controls Inc, Attleboro, Mass
82807	Milwaukee Resistor Co, Milwaukee, Wisc
82877	Rotron Mfg Co. Inc., Woodstock, N.Y. 12498
83033	Messner Mfg. (Maguire Ind) Mt. Carmel, Ill.
83058	Carr Fastener Co, Cambridge, Mass
83186	Victory Engineering, Springfield, N.J. 07081
83361	Bearing Specialty Co, San Francsco, Calif.
83587	Solar Electric Corp, Warren, Penn.
83740	Union Carbide Corp, New York, N.Y 10017
83781	National Electronics Inc, Geneva, Ill.
84411	TRW Capacitor Div, Ogallala, Nebr
84835	Lehigh Metal Prods, Cambridge, Mass 02140
84971	TA Mfg Corp, Los Angeles, Calif.
86577	Precision Metal Prods, Stoneham, Mass 02180
86684	RCA (Elect. Comp & Devl, Harrison, N.J.
86687	REC Corp, New Rochelle, N.Y. 10801
86800	Cont Electronics Corp, Brooklyn, N.Y. 11222
88140	Cutler-Hammer Inc, Lincoln, Ill.
88219	Gould Nat. Batteries Inc, Trenton, N.J.
88419	Cornell-Dubilier, Fuquay-Varina, N.C.
88627	K & G Mfg Co, New York, N.Y.
89482	Holtzer-Cabot Corp, Boston, Mass
89665	United Transformer Co, Chicago, Ill.
90201	Mallory Capacitor Co, Indianapolis, Ind.
90634	Gulton Industries, Inc, Metuchen, N.J 08840
90750	Westinghouse Electric Corp, Boston, Mass
90952	Hardware Products Co, Reading, Penn 19602
91032	Continental Wire Corp, York, Penn. 17405
91146	ITT (Cannon Electric Inc), Salem, Mass
91210	Gerber Mfg. Co, Mishawaka, Ind
91293	Johanson Mfg Co, Boonton, N.J. 07005
91506	Augat Inc, Attleboro, Mass. 02703
91598	Chandler Co, Wethersfield, Conn 06109
91637	Dale Electronics Inc, Columbus, Nebr
91662	Elco Corp, Willow Grove, Penn.
91719	General Instruments, Inc, Dallas, Texas
91916	Mephisto Tool Co. Inc, Hudson, N.Y. 12534
91929	Honeywell Inc, Freeport, Ill
92519	Electra Insul Corp, Woodside, L.I., N.Y
92678	E.G.&G., Boston, Mass
92739	Ampex Corp, Redwood City, Calif. 94063
93332	Sylvania Elect Prods, Inc, Woburn, Mass
93618	R. & C. Mfg. Co. of Penn. Inc, Ramey, Penn.
93916	Cramer Products Co, New York, N.Y. 10013
94144	Raytheon Co, Components Div, Quincy, Mass
94154	Tung Sol Electric Inc, Newark, N.J.
94271	Weston Instruments Inc, Archibald, Penn. 18403
94589	Dickson Co., Chicago, Ill 60619
94800	Atlas Industrial Corp., Brooklyn, N.H.
95076	Garde Mfg. Co., Cumberland, R.I
95121	Quality Components Inc, St. Mary's, Penn.
95146	Alco Electronics Mfg Co, Lawrence, Mass
95238	Continental Connector Corp, Woodside, N.Y.
95275	Vitramon, Inc, Bridgeport, Conn.
95354	Methode Mfg Co, Chicago, Ill.
95412	General Electric Co., Schenectady, N.Y.
95794	Anaconda Amer Brass Co, Torrington, Conn.
96095	Hi-Q Div. of Aerovox Corp, Orlean, N.Y.
96214	Texas Instruments Inc, Dallas, Texas 75209
96256	Thordarson-Meissner, Mt. Carmel, Ill.
96341	Microwave Associates Inc, Burlington, Mass
96791	Amphenol Corp, Janesville, Wisc 53545
96906	Military Standards
97684	Models Inc, North Bergen, N.J.
98291	Sealectro Corp, Mamaroneck, N.Y. 10544
98474	Comper Inc, Burlingame, Calif.
98821	North Hills Electronics Inc., Glen Cove, N.Y.
99112	Metavac Inc, Flushing, N.Y. 11358
99180	Transitron Electronics Corp, Melrose, Mass
99313	Varian, Palo Alto, Calif. 94303
99378	Atlee Corp, Winchester, Mass. 01890
99800	Delevan Electronics Corp, E. Aurora, N.Y.

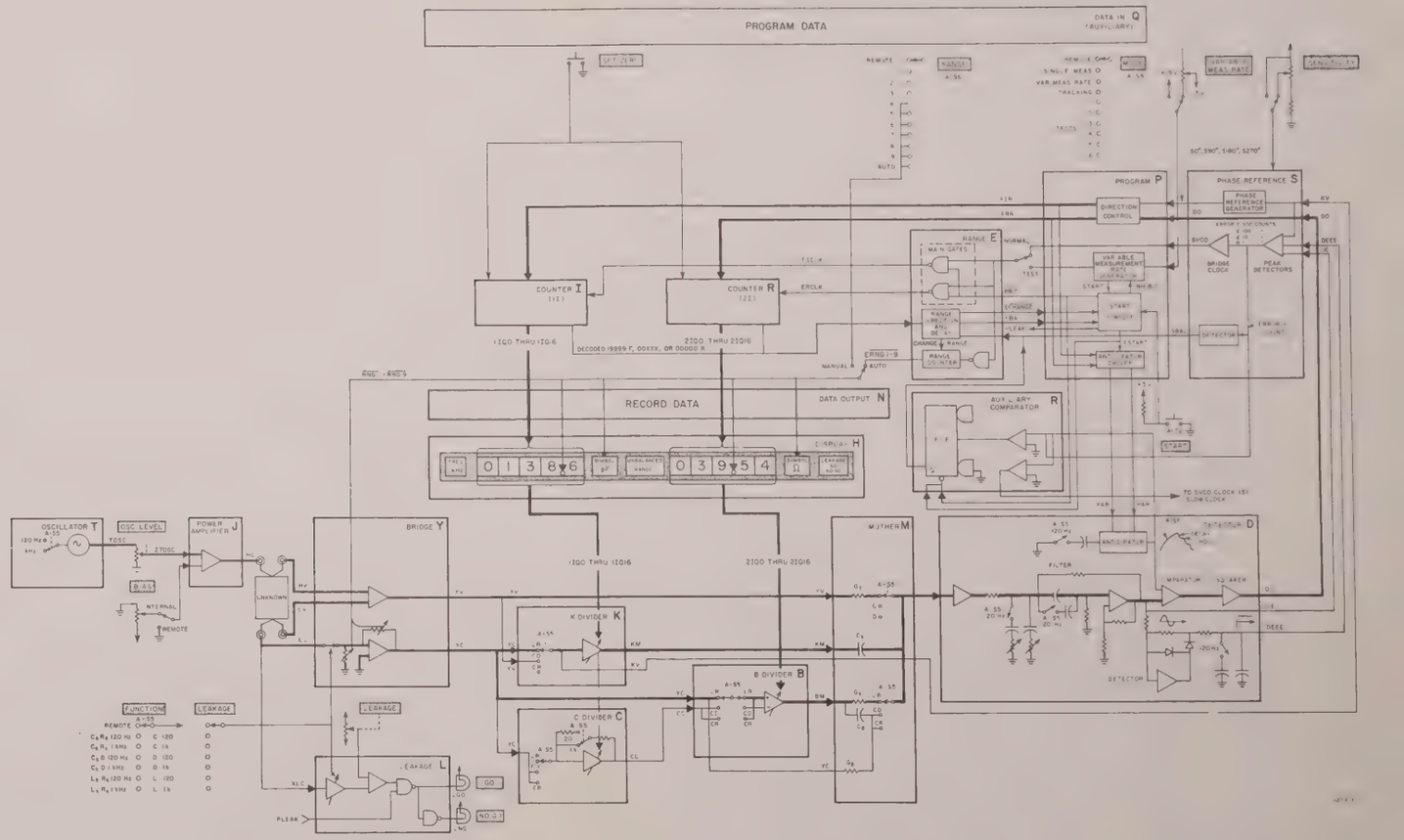


Figure 6-3. Detailed block diagram of the 1683.

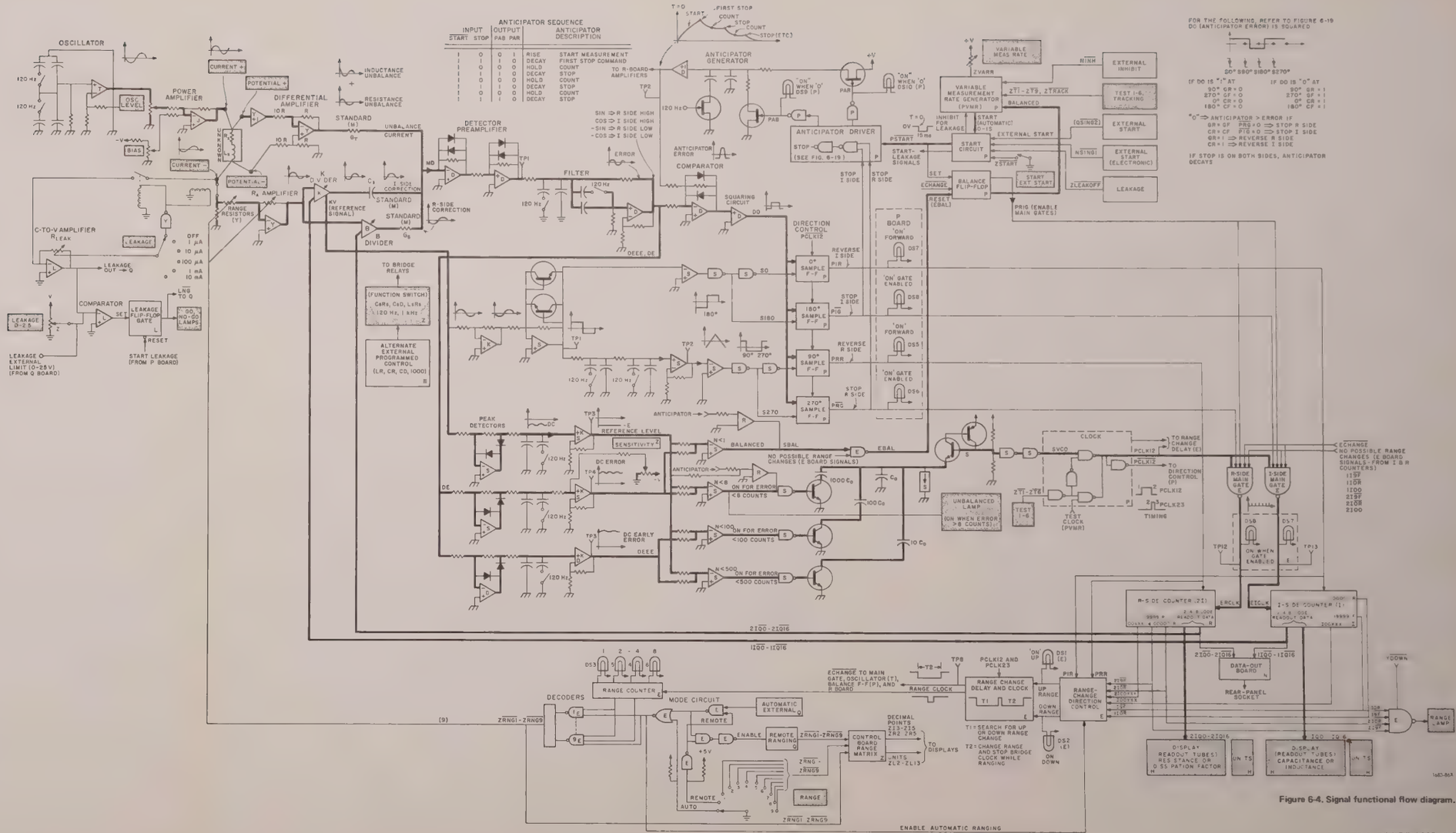


Figure 6-4. Signal functional flow diagram.

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
	B-DIVIDER BOARD (P/N 1683-4700) ELECTRICAL REPLACEABLE PARTS				
	CAPACITORS				
C4	Ceramic, 0.02 µf, +80-20%	4402-3200	01121	35-203W	5910-974-5698
C5	Tantalum, 10 µF ±20%	4450-5200	56289	150D156X0020B2	5910-855-6335
*C6	Ceramic, 470 pF ±5%, 500 V	4404-1475	72982	831, 470 pF	
C8	Tantalum, 68 µF ±20%	4450-5615	80183	150D686X0015R2	
C9	Ceramic, 0.47 µF +80-20%	4402-3200	01121	35-203W	5910-974-5698
C11	Tantalum, 68 µF ±20%	4450-5616	80183	150D686X0015R2	
C12	Ceramic, 0.001 µf +80-20%	4404-2109	72982	831, 0.001 µF +80-20%	5910-075-9607
C13	Ceramic, 1.7 pF ±10%	4400-0279	7848	GA, 2.7 pF ±10%	
C14	Ceramic, 10 pF ±10%	4400-1100	78488	GA, 10 pF ±10%	5961-061-8236
C15	Trimmer, 5-25 pF	4910-1150	72982	557-051, U2PO	
C18 and C19	Ceramic, 1.8 pF ±5%	4400-0180	72982	831, 1.8 pF 5%	
C20 and C21	Ceramic, 0.47 pF ±10%	4400-1200	78488	GA, 0.47 pF 10%	
C24	Ceramic, 0.1 µF +80-20%	4403-4100	80183	CC63, 0.1 µF +80-20%	5910-974-5699
C25	Ceramic, 1 µF ±20%	4400-2070	80183	5C13, 1 µF 20%	5910-083-6445
C26	Ceramic, 0.1 µF +50-20%	4403-4100	80183	CC63, 0.1 µF +80-20%	5910-974-5699
	DIODES				
CR1 thru CR3	Type IN3604	6082-1001	24446	IN3604	5961-995-2199
CR4 and CR5	Type IN695	6082-1014	24446	IN695	
CR6	Type IN3604	6082-1001	24446	IN3604	5961-995-2199
CR7 and CR8	Type IN695	6082-1014	24446	IN695	
CR9 thru CR11	Type IN3604	6082-1001	24446	IN3604	5961-995-2199
CR12 and CR13	Type IN695	6082-1014	24446	IN695	
CR14	Type IN3604	6082-1001	24446	IN3604	5961-995-2199
CR15	Type IN695	6082-1014	24446	IN695	
CR16	Type IN695	6082-1014	24446	IN695	
CR17 thru CR19	Type IN3604	6082-1001	24446	IN3604	5961-995-2199
CR20 and CR21	Type IN695	6082-1014	24446	IN695	
CR22	Type IN3604	6082-1001	24446	IN3604	5961-995-2199
CR23 and CR24	Type IN695	6082-1014	24446	IN695	
CR25 and CR27	Type IN3604	6082-1001	24446	IN3604	5961-995-2199
CR28 and CR29	Type IN695	6082-1014	24446	IN695	
CR30	Type IN3604	6082-1001	24446	IN3604	5961-995-2199
CR31	Type IN695	6082-1014	24446	IN695	
CR32	Type IN695	6082-1014	24446	IN695	
CR33	Type IN3604	6082-1001	24446	IN3604	5961-995-2199
CR36 and CR37	Type IN3604	6082-1001	24446	IN3604	5961-995-2199
CR52 and CR53	Type IN3604	6082-1001	24446	IN3604	5961-995-2199
CR54	Type IN759A	6083-1014	81349	IN759A	5961-846-9157
	INTEGRATED CIRCUITS				
IC1	Digital	5431-9362	07263	DTµL-936	
	RELAYS				
K24S thru K26S	Reed switch	6090-0800	30874	76586S	
K30S	Reed switch	6090-0800	30874	76586S	
K39S	Reed switch	6090-0800	30874	76586S	
K24L thru K26L	Reed coil	6090-1130	71707	XU-8242-D	
K30L	Reed coil	6090-1130	71707	XU-8242-D	
K39L	Reed coil	6090-1130	71707	XU-8242-D	
	RESISTORS				
R1 thru R5	Comp., 2.7 kΩ ±5%	6099-2275	75042	BTS, 2.7 kΩ ±5%	
R6 thru R17	Comp., 18 kΩ ±5%	6099-3185	75042	BTS, 18 kΩ ±5%	5905-687-0000
R18 thru R22	Comp., 2.4 kΩ ±5%	6099-2245	75042	BTS, 2.4 kΩ 5%	5905-683-7724

*Laboratory-selected value.

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
R23 thru R34	Comp., 16 kΩ ±5%	6099-3165	75042	BTS, 16 kΩ 5%	
R35 thru R39	Comp., 10 kΩ ±5%	6099-3105	75042	BTS, 10 kΩ 5%	5905-683-2238
R40 thru R51	Comp., 27 kΩ ±5%	6099-3275	75042	BTS, 27 kΩ 5%	5905-683-3838
R52 thru R56	Comp., 10 kΩ ±5%	6099-3105	75042	BTS, 10 kΩ 5%	5905-683-2238
R57 thru R68	Comp., 33 kΩ ±5%	6099-3335	75042	BTS, 33 kΩ 5%	
R69 thru R73	Comp., 7.5 kΩ ±5%	6099-2755	75042	BTS, 2.5 kΩ ±5%	
R74 thru R85	Comp., 33 kΩ ±5%	6099-3335	75042	BTS, 33 kΩ ±5%	
R86	Wirewound, 40 kΩ ±.01%, 1 W	6983-5011	24655	6983-5011	
R88	Wire wound, 80 kΩ ±0.01%	6983-5015	24655	6983-5015	
R89 thru R91	Wire wound, 40 kΩ ±0.01%	6983-5011	24655	6983-5011	
R92	Wire wound, 16.0012 ±0.01%	6982-5008	24655	6982-5008	
R93 and R94	Wire wound, 13.333 kΩ ±0.01%	6982-5009	24655	6982-5009	
R96	Wire wound, 160 kΩ ±0.1%	6983-6011	24655	6983-6011	
R97 and R98	Wire wound, 80 kΩ ±0.1%	6983-5012	24655	6983-5012	
R99	Wire wound, 80 kΩ ±0.01%	6983-5015	24655	6983-5015	
R100	Wire wound, 32.002 kΩ ±0.1%	6983-5013	24655	6983-5013	
R101 and R102	Wire wound, 204.48 kΩ ±0.1%	6983-6010	24655	6983-6010	
R103 thru R107	Film, 200 kΩ ±1%	6250-3200	75042	CEA, 200 kΩ 1%	
R108	Film, 79.6 kΩ ±5%	6351-2796	75042	CEB, 79.6 kΩ ±5%	
R109	Film, 2.21 MΩ ±1%	6350-4221	75042	CEB, 2.21 MΩ ±1%	
R110	Film, 2.15 MΩ ±1%	6350-4215	75042	CEB, 2.15 Ω 1%	
R112 thru R116	Comp., 200 kΩ ±5%	6099-4205	75042	BTS, 200 kΩ ±5%	5905-681-8821
R117	Comp., 82 kΩ ±5%	6099-3825	75042	BTS, 82 kΩ ±5%	
R118 and R119	Comp., 22 MΩ ±5%	6099-6225	75042	BTS, 22 MΩ ±5%	
R121	Wire wound, 39.8 kΩ ±0.01%	6983-5014	24655	6983-5014	
R122 and R123	Film, 243 Ω ±1%	6250-0243	75042	CEA, 243 Ω 1%	
R124	Power, wire wound 5 kΩ ±10%	6051-2509	80294	3007P-1-502	
R125	Comp., 6.2 kΩ ±5%	6099-2625	75042	BTS, 6.2 kΩ ±5%	5905-682-4100
R126	Power, wire wound 91 Ω ±5%	6099-0915	75042	BTS, 91 Ω ±5%	
R127	Comp., 51 kΩ ±5%	6099-3515	75042	BTS, 51 kΩ ±5%	5905-682-4103
R128	Comp., 22 kΩ ±5%	6099-3225	75042	BTS, 22 kΩ ±5%	5905-687-0002
R129	Comp., 51 kΩ ±5%	6099-3515	75042	BTS, 51 kΩ 5%	5905-682-4103
R131	Comp., 750 Ω ±5%	6099-1755	75042	BTS, 750 Ω ±5%	
R132	Comp., 3.9 kΩ ±5%	6099-2395	75042	BTS, 3.9 kΩ ±5%	
R133	Power, wire wound, 2.5 kΩ ±10%	6051-2259	96791	2600 PC, 2.5 kΩ ±10%	
R134	Comp., 680 Ω ±5%	6099-1685	75042	BTS, 680 Ω ±5%	
R135	Power, wire wound, 240 Ω ±5%	6099-1245	75042	BTS, 240 Ω ±5%	
R136	Power, wire wound, 100 Ω ±5%	6099-1105	75042	BTS, 100 Ω ±5%	
R138	Wire wound, 39.8 kΩ ±0.01%	6983-5014	24655	6983-5014	
R139	Power, wire wound, 470 Ω ±5%	6099-1475	75042	BTS, 470 Ω ±5%	5905-683-2242
R140	Comp., 220 Ω ±5%	6100-1225	01121	RC20GF221J	5905-279-3513
R142	Comp., 47 kΩ ±5%	6099-3475	75042	BTS, 47 kΩ ±5%	5905-683-2246
	TRANSISTORS				
Q1 thru Q17	Type 2N4125	8210-1125	93916	2N4125	
Q18 thru Q22		8210-1174	24655	8210-1174	
Q23 thru Q34	Type 2N1302	8210-1018	96214	2N1302	5960-086-0039
Q35 thru Q39	Type GA2390	8210-1081	01295	GA2390	
Q40 thru Q51	Type 2N1303	8210-1019	96214	2N1303	
Q52	Type TD-100	8210-1130	56289	TD-100	
Q54	Type 4JX16A733	8210-1083	24454	4JX16A733	
Q55	Type 2N4250	8210-1135	93916	2N4250	
Q56	Type 2N4123	8210-1123	93916	2N4123	

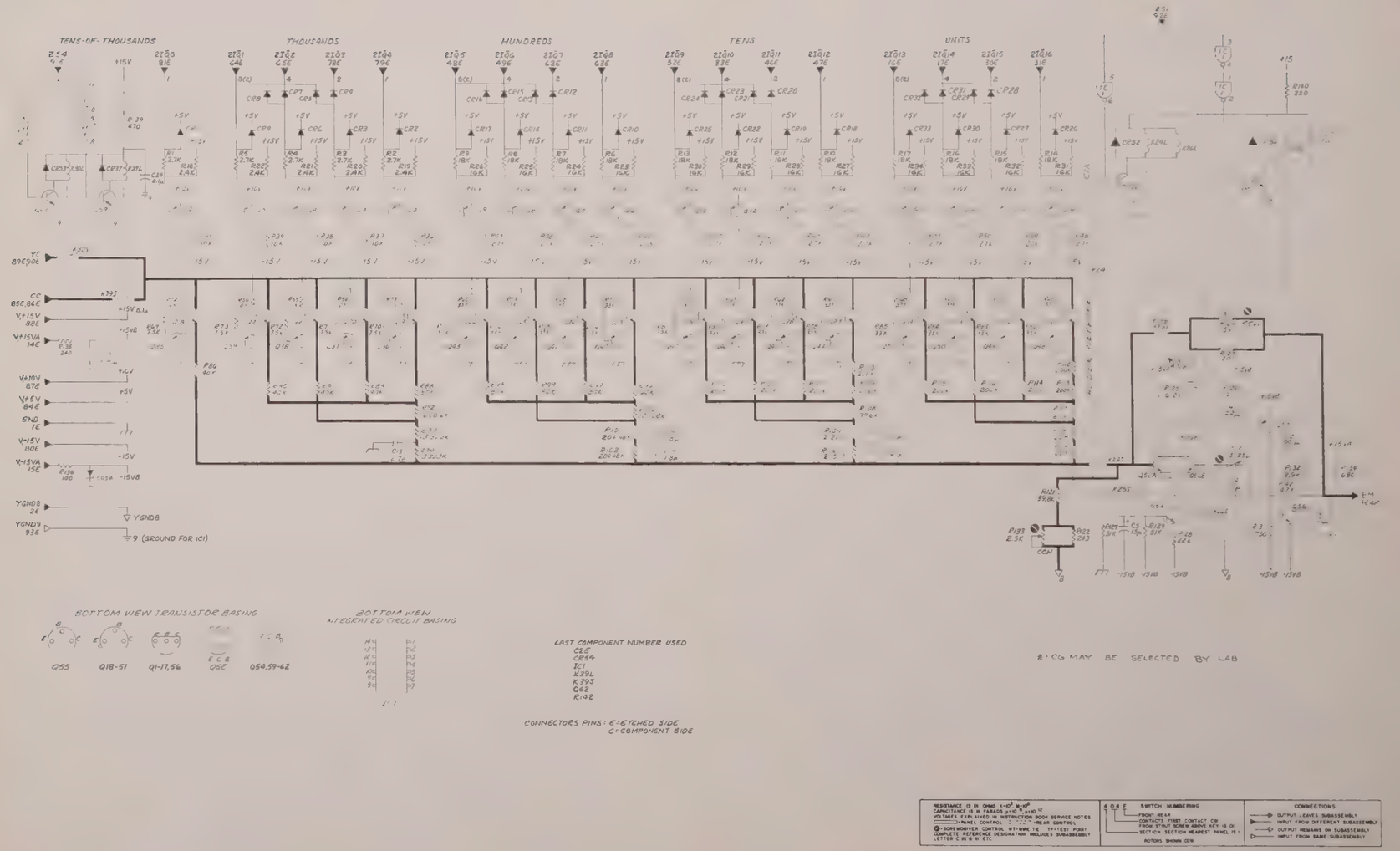


Figure 6-5. B-divider board schematic, B.

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
	C-DIVIDER BOARD (P/N 1683-4718) ELECTRICAL REPLACEABLE PARTS				
CAPACITORS					
C4	Ceramic, .180 pF, ±10%, 500 V	4404-1188	72982	831, 180 pF, ±10%	
C5	Ceramic, 0.02 µF +80-20%	4402-3200	01121	35-203W	5910-974-5698
C6	Tantalum	4450-5200	56289	150D156X0020B2	5910-855-6335
C7	Ceramic, 0.001 µF +80-20%	4404-2109	72982	831, 0.001 µF +80-20%	5910-075-9607
C8	Ceramic, 0.02 µF +80-20%	4402-3200	01121	35-203W	5910-974-5698
C10	Tantalum, 0.68 µF 20%	4450-5615	80183	150D686X0015R2	
C12	Tantalum, 68 µF ±20%, 15 V	4450-5615	80183	150D686X0015R2	
C13	Ceramic, 5.1 pF ±5%	4400-0511	78488	GA, 5.1 pF ±5%	
C22	Ceramic, 10 pF, ±5%, 500 V	4404-0108	72982	831, 10 pF, ±10%	
C23	Ceramic, 0.1 µF +80-20%	4403-4100	80131	CC63, 0.1 µF +80-20%	
C24	Ceramic, 0.68 pF ±10%	4400-0068	78488	GA, 0.68 pF ±10%	
DIODES					
CR1 and CR2	Type 1N3604	6082-1001	24446	5961-995-2199	
INTEGRATED CIRCUITS					
IC1	Digital	5431-9362	96214	SN15836N	
RELAYS					
K29S	Reed switch	6090-0800	30874	76586S	
K40S	Reed switch	6090-0800	30874	76586S	
K29L	Reed coil	6090-1130	71707	XU-8242-D	
K40L	Reed coil	6090-1130	71707	XU-8242-D	
RESISTORS					
R52 thru R56	Comp., 10 kΩ ±5%	6099-3105	75042	BTS, 10 kΩ ±5%	5905-683-2238
R57 thru R68	Comp., 33 kΩ ±5%	6099-3335	75042	BTS, 33 kΩ ±5%	
R69 thru R73	Comp., 7.5 kΩ ±5%	6099-2755	75042	BTS, 7.5 kΩ ±5%	
R74 thru R85	Comp., 33 kΩ ±5%	6099-3335	75042	BTS, 33 kΩ ±5%	
R86	Wire wound, 40 kΩ ±.01%, 1 W	6983-5011	24655	6983-5011	
R88	Wire wound, 80 kΩ ±0.01%	6983-5015	24655	6983-5015	
R89 thru R91	Wire wound, 40 kΩ ±0.01%	6983-5011	24655	6983-5011	
R92	Wire wound, 16.0012 kΩ ±0.01%	6982-5008	24655	6982-5008	
R93 and R94	Wire wound, 13.333 kΩ ±0.01%	6982-5009	24655	6982-5009	
R96	Wire wound, 160 kΩ ±0.1%	6983-6011	24655	6983-6011	
R97 and R98	Wire wound, 80 kΩ ±0.1%	6983-5012	24655	6983-5012	
R99	Wire wound, 80 kΩ ±0.01%	6983-5015	24655	6983-5015	
R100	Wire wound, 32.002 kΩ 0.1%	6983-5013	24655	6983-5013	
R101 and R102	Wire wound, 48 kΩ ±0.1%	6983-6010	24655	6983-6010	6983-6010
R103 thru R107	Film, 200 kΩ ±1%	6250-3200	75042	CEA, 200 kΩ ±1%	
R108	Film, 79.6 kΩ ±5%	6351-2796	75042	CEB-TO, 79.6 kΩ ±1%	
R109	Film, 2.21 MΩ ±1%	6350-4221	75042	CEB, 2.21 MΩ ±1%	
R110	Film, 2.15 MΩ ±1%	6350-4215	75042	CEB, 2.15 MΩ ±1%	
R112 thru R116	Comp., 200 kΩ ±5%	6099-4205	75042	BTS, 200 kΩ ±5%	5905-681-8821
R117	Comp., 82 kΩ ±5%	6099-3825	75042	BTS, 82 kΩ ±5%	
R118 and R119	Comp., 22 MΩ ±5%	6099-6225	75042	BTS, 22 MΩ ±5%	
R121	Pot., wire wound 2.5 kΩ ±10%	6051-2259	96791	2600PC, 2.5 kΩ ±10%	
R122	Film, 57.6 Ω ±1%	6250-9576	75042	CEA, 57.6 Ω ±1%	
R123	Wire wound, 4.98 kΩ ±0.01%	6982-4001	24655	6982-4001	
R124	Wire wound, 25 kΩ ±0.01%	6983-5016	24655	6983-5016	
R125	Pot., wire wound, 20 kΩ ±10%	6051-3209	02660	2600PC, 20 kΩ ±10%	
R126	Film, 147 Ω ±1%	6250-0147	75042	CEA, 147 Ω ±1%	
R127	Pot., wire wound, 6.2 kΩ ±5%	6099-2625	75042	BTS, 6.2 kΩ ±5%	5905-682-4100
R128	Pot., wire wound, 22 kΩ ±5%	6099-3225	75042	BTS, 22 kΩ ±5%	5905-687-0002
R129 and R130	Comp., 51 kΩ ±5%	6099-3515	75042	BTS, 51 kΩ ±5%	5905-682-4103
R131	Comp., 150 Ω ±5%	6099-1155	75042	BTS, 150 Ω ±5%	5905-683-2243
R133 and R134	Comp., 240 Ω ±5%	6099-1245	75042	BTS, 240 Ω ±5%	
R137	Comp., 180 Ω ±5%	6099-1185	75042	BTS, 180 Ω ±5%	5905-682-4107
R138	Comp., 680 Ω ±5%	6099-1685	75042	BTS, 680 Ω ±5%	
R139	Comp., 750 Ω ±5%	6099-1755	75042	BTS, 750 Ω ±5%	
R140	Comp., 220 Ω ±5%	6100-1225	01121	RC20GF221J	5905-279-3513

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
TRANSISTORS					
Q15 thru Q22		8210-1174	24655	8210-1174	
Q23 thru Q34	Type 2N1302	8210-1018	96214	2N1302	
Q35 thru Q39	Type GA2390	8210-1081	96214	GA2390	
Q40 thru Q51	Type 2N1303	8210-1019	96214	2N1303	
Q52	Type TD-100	8210-1130	56289	TD-100	
Q54	Type #4JX16A733	8210-1083	24454	#4JX16A733	
Q55	Type 2N4250	8210-1135	07263	2N4250	
Q56	Type 2N4123	8210-1123	04713	2N4123	
Q59 and Q60	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749

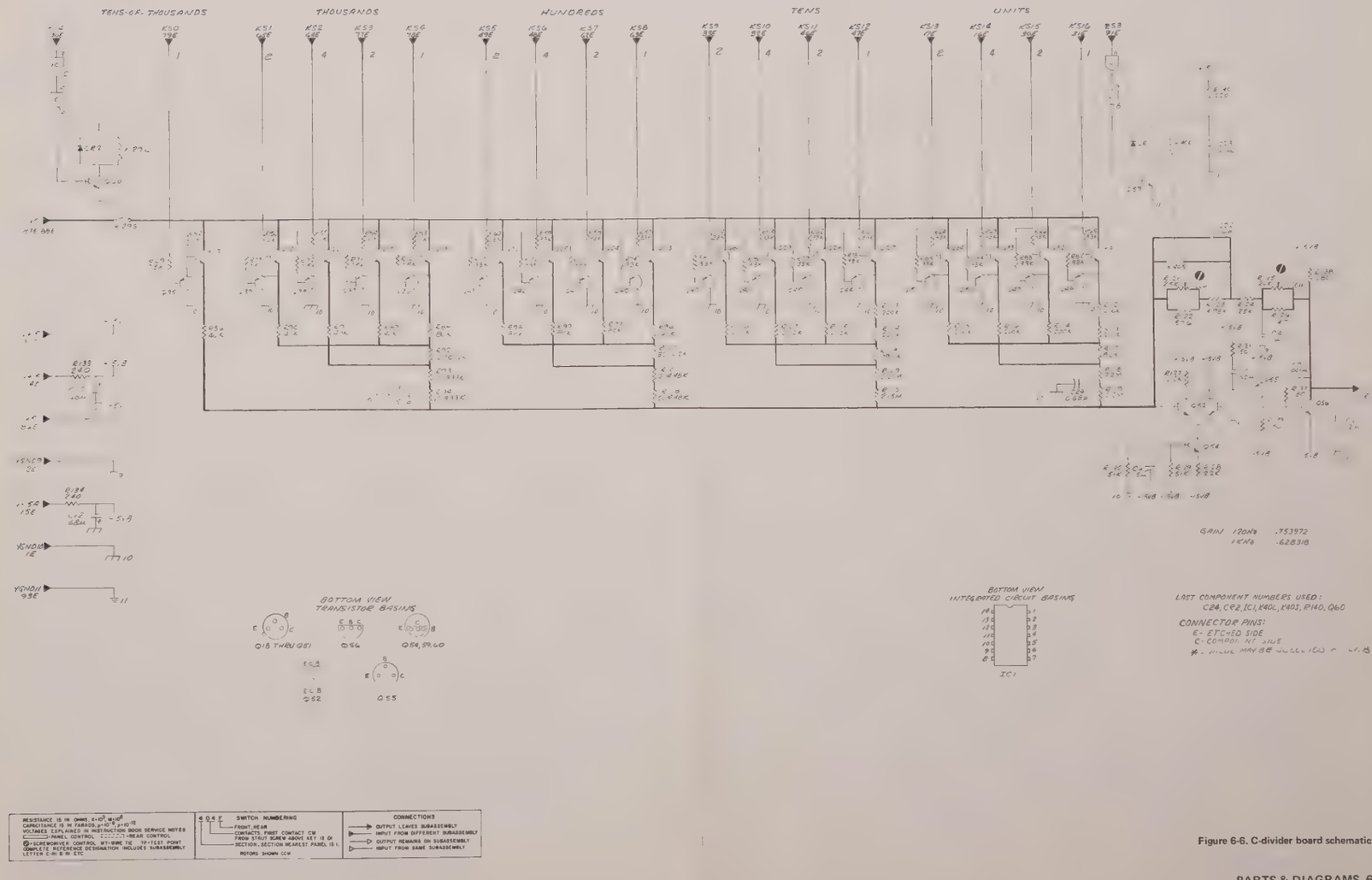


Figure 6-6. C-divider board schematic, C.

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
	DETECTOR BOARD (P/N 1683-4730) ELECTRICAL REPLACEABLE PARTS				
CAPACITORS					
C1	Ceramic, 100 pF +80-20%	4404-1109	72982	831, 100 pF +80-20%	
C2	Ceramic, 1000 pF +80-20%	4406-3109	72982	811, .01 µF +80-20%	5910-977-5779
C3	Tantalum, 47 µF ±20%	4450-5500	56289	150D476X0006B2	5910-752-4185
C4	Tantalum, 120 µF ±20%	4450-5616	56289	150D127X0010R2	
C5	Tantalum, 2.2 µF ±20%	4450-4500	56289	150D225X0020A2	5910-976-4604
C6	Tantalum, 120 µF ±20%	4450-5616	56289	150D127X0010R2	
C7	Ceramic, 220 pF ±10%	4404-1228	72982	831, 220 pF 10%	
C8	Ceramic, .01 µF +80-20% 100 V	4401-3100	80131	CC61, .01 µF +80-20%	
C11	Ceramic, .01 µF +80-20% 100 V	4401-3100	80131	CC61, .01 µF +80-20%	5910-974-5697
C12 and					
C13	Ceramic, 100 pF +80-20%	4404-1109	72982	831, 100 pF +80-20%	
C14	Plastic, 0.75 µF ±5% 100 V	4860-8006	84411	663 UW 0.75 µF ±5%	
C15	Plastic, 0.1 µF ±5% 100 V	4860-8254	84411	663 UW 0.1 µF ±5%	
C16	Ceramic, 100 pF +80-20%	4404-1109	72982	831, 100 pF +80-20%	
C17	Plastic, .01 µF ±2% 100 V	4860-7650	84411	663 UW .01 µF ±2%	
C18	Plastic, .0787 µF ±2% 100 V	4860-7910	84411	663 UW .0787 µF 2%	
C19	Plastic, .01 µF ±2% 100 V	4860-7650	84411	663 UW .01 µF ±2%	
C20	Plastic, .0787 µF ±2% 100 V	4860-7910	84411	663 UW .0787 µF ±2%	
C21	Ceramic, 39 pF ±10%	4404-0398	72982	831, 39 pF ±10%	
C23	Tantalum, 68 µF ±2%	4450-5615	80183	150D686X0015R2	
C24	Ceramic, 39 pF ±10%	4404-0398	72982	831, 39 pF ±10%	
C25 and					
C26	Tantalum, 68 µF ±20%	4450-5615	80183	150D686X0015R2	
C27	Tantalum, 330 µF ±20%	4450-5708	37942	TT 330 µF ±20%	
C28	Ceramic, 1000 pF +80-20%	4406-3109	72982	811, .01 µF +80-20%	5910-977-5779
C29	Tantalum, 3.3 µF ±20%	4450-4600	56289	150D335X0015A2	5910-837-9325
C30	Tantalum, 1 µF ±20%	4450-4300	56289	150D105X0035A2	5910-726-5003
C31	Tantalum, 6.8 µF ±20%	4450-5000	56289	150D685X0035B2	5910-814-5869
C34 thru					
C36	Ceramic, 39 pF ±10%	4404-0398	72982	831, 39 pF ±10%	
C37	Ceramic, 0.1 µF +80-20%	4403-4100	80131	CC63, 1 µF +80-20%	5910-974-5699
C38	Ceramic, 0.1 µF +80-20%	4400-2070	80183	5C13, .1 µF ±20%	5910-083-6445
C40	Tantalum, 47 µF ±20%	4450-5500	56289	150D476X006B2	5910-752-4185
C41	Ceramic, 220 pF ±10%	4404-1228	72982	831, 220 pF ±10%	
C42	Ceramic, 2.2 µF ±20% 25V	4400-2080	80183	5C13, 2.2 µF ±20%	
C43 and					
C44	Ceramic, 0.1 µF +80-20%	4403-4100	80131	CC63, .1 µF +80-20%	5910-974-5699
C46	Ceramic, .22 µF ±20%	4400-2052	80183	5C13, .22 µF ±20%	5910-974-5694
C47	Ceramic, 2.2 µF ±20%	4400-2080	80183	5C13, 2.2 µF ±20%	
C48	Ceramic, 0.1 µF ±20%	4400-2050	80183	5C13, 0.1 µF ±20%	5910-080-4646
C49	Ceramic, 300 pF ±10%	4404-1338	72982	831, 330 pF ±10%	5910-974-5702
DIODES					
CR 1 thru					
CR 9	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR 11	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR12	Type 1N753A	6083-1006	07910	1N753A	5961-752-6121
CR13	Type 748A	6083-1002	07910	1N748A	5960-800-3973
CR14	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR15	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR16	Type 1N695	6082-1014	24446	1N695	5961-087-6047
CR17	Type 1N758A	6083-1012	07910	1N758A	
CR18 and					
CR19	Type 1N645	6082-1016	24446	1N645	5961-087-6047
CR20 and					
CR21	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR22	Type 1N748A	6083-1002	07910	1N748A	5960-800-3973
CR23 and					
CR24	Type 1N746	6083-1005	07910	1N746	5960-984-3570
CR25	Type 1N4009	6082-1012	24446	1N4009	5961-892-8700
CR26	Type 1N4009	6082-1012	24446	1N4009	5961-892-8700
INTEGRATED CIRCUITS					
IC1	Linear	5432-1005	07263	U6E7739393	
IC3 and					
IC4	Linear	5432-1004	12040	LM301A	
IC5	Linear	5432-7101	07263	U5B771039X	
IC6	Digital	5431-9362	96214	SN15836N	
IC7 and					
IC9	Linear	5432-1004	12040	LM301A	
RELAYS					
K1L	Reed coil	6090-1130	71707	XU-8242-P	
K2L, K3L, K4L	Reed coil	6090-1130	71707	XU-8242-P	
K1S	Reed switch	6090-0800	30874	76586S	
K2S, K3S, K4S	Reed switch	6090-0800	30874	76586S	

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
RESISTORS					
R1	Comp, 20 kΩ ±5%	6099-3205	75042	BTS, 20 kΩ ±5%	5905-686-3368
R2	Comp, 82 kΩ ±5%	6099-3825	75042	BTS, 82 kΩ ±5%	
R3	Comp, 27 kΩ ±5%	6099-3275	75042	BTS, 27 kΩ ±5%	5905-683-3838
R4	Comp, 3 kΩ ±5%	6099-2305	75042	BTS, 3 kΩ ±5%	5905-682-4097
R5	Comp, 3 kΩ ±5%	6099-2305	75042	BTS, 3 kΩ ±5%	5905-682-4097
R6	Comp, 6.8 kΩ ±5%	6099-2685	75042	BTS, 6.8 kΩ ±5%	5905-686-9997
R7 and					
R8	Comp, 62 kΩ ±5%	6099-3625	75042	BTS, 62 kΩ ±5%	
R9	Comp, 3 kΩ ±5%	6099-2305	75042	BTS, 3 kΩ ±5%	5905-682-4097
R10	Comp, 2.4 kΩ ±5%	6099-2245	75042	BTS, 2.4 kΩ ±5%	5905-683-7724
R11	Comp, 2 kΩ ±5%	6099-2205	75042	BTS, 2 kΩ ±5%	5905-686-3370
R12	Comp, 2.4 kΩ ±5%	6099-2245	75042	BTS, 2.4 kΩ ±5%	5905-683-7724
R14	Comp, 4.3 kΩ ±5%	6099-2435	75042	BTS, 4.3 kΩ ±5%	
R15	Comp, 20 kΩ ±5%	6099-3205	75042	BTS, 20 kΩ ±5%	5905-686-3368
R21 and					
R22	Comp, 16 kΩ ±5%	6099-3165	75042	BTS, 16 kΩ ±5%	
R23	Comp, 20 kΩ ±5%	6099-3205	75042	BTS, 20 kΩ ±5%	5905-686-3368
R24	Comp., 82 kΩ ±5%, 1/4 W	6099-3825	75042	BTS, 82 kΩ, ±5%	
R25	Comp, 27 kΩ ±5%	6099-3275	75042	BTS, 27 kΩ ±5%	5905-683-3838
R26	Comp, 20 kΩ ±5%	6099-3205	75042	BTS, 20 kΩ ±5%	5905-686-3368
R27	Comp, 27 kΩ ±5%	6099-3275	75042	BTS, 27 kΩ ±5%	5905-683-3838
R28	Comp, 82 kΩ ±5%	6099-3825	75042	BTS, 82 kΩ ±5%	
R29	Comp, 516 kΩ ±5%	6099-2565	75042	BTS, 5.6 kΩ ±5%	5905-691-0195
R30	Pot.,wire wound	6051-2109	02660	2600-PC, 1 kΩ ±10%	
R31	Comp., 30 kΩ ±5%, 1/4 W	6099-3305	75042	BTS, 30 kΩ, ±5%	5905-803-2908
R32	Comp, 6.2 kΩ ±5%	6099-2625	75042	BTS, 6.2 kΩ ±5%	5905-682-4100
R33	Comp, 30 kΩ ±5%	6099-3305	75042	BTS, 30 kΩ ±5%	5905-803-2908
R34	Comp, 18 kΩ ±5%	6099-3185	75042	BTS, 18 kΩ ±5%	5905-687-0000
R35	Comp, 2.4 kΩ ±5%	6099-2245	75042	BTS, 2.4 kΩ ±5%	5905-683-7724
R36	Comp, 60.4 kΩ ±1%	6250-2604	75042	CEA, 60.4 kΩ ±1%	5905-755-0675
R37	Film , 16.2 kΩ ±1%	6350-2162	75042	CEB, 16.2 kΩ ±1%	5905-702-6460
R38	Film, 1.05 kΩ ±1%	6250-1105	75042	CEA, 1.05 kΩ ±1%	5905-683-5713
R39	Film, 22.1 kΩ ±1%	6250-2221	75042	CEA, 22.1 kΩ ±1%	5905-702-5793
R40	Film, 2.94 kΩ ±1%	6250-1294	75042	CEA, 2.94 kΩ ±1%	
R41	Pot., wire wound	6051-2109	02660	2600-PC, 1 kΩ ±10%	
R42	Pot., wire wound	6051-2109	02660	2600-PC, 1 kΩ ±10%	
R43	Comp, 10 kΩ ±5%	6099-3105	75042	BTS, 10 kΩ ±5%	5905-683-2238
R45	Comp, 3 kΩ ±5%	6099-2305	75042	BTS, 3 kΩ ±5%	5905-682-4097
R50	Comp, 360 Ω ±5%	6099-1365	75042	BTS, 360 Ω ±5%	
R51	Comp, 5.1 kΩ ±5%	6099-2515	75042	BTS, 5.1 kΩ ±5%	5905-683-2241
R52	Comp, 6.2 kΩ ±5%	6099-2625	75042	BTS, 6.2 kΩ ±5%	5905-682-4100
R53	Comp, 180 Ω ±5%	6099-1185	75042	BTS, 180 Ω ±5%	5905-682-4107
R54	Comp, 200 Ω ±5%	6099-1205	75042	BTS, 200 Ω ±5%	5905-683-2239
R55	Comp, 180 Ω ±5%	6099-1185	75042	BTS, 180 Ω ±5%	5905-682-4107
R61 and					
R62	Comp, 5.1 kΩ ±5%	6099-2515	75042	BTS, 5.1 kΩ ±5%	5905-683-2241
R63 and					
R64	Comp, 5.6 kΩ ±5%	6099-2565	75042	BTS, 5.6 kΩ ±5%	5905-691-0195
R65	Comp, 470 Ω ±5%	6099-1475	75042	BTS, 470 Ω ±5%	5905-683-2242
R67	Comp, 2 kΩ ±5%	6099-2205	75042	BTS, 2 kΩ ±5%	5905-686-3370
R68	Comp, 47 kΩ ±5%	6099-3475	75042	BTS, 47 kΩ ±5%	5905-683-2246
R69	Comp, 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R70	Comp, 10 kΩ ±5%	6099-3105	75042	BTS, 10 kΩ ±5%	5905-683-2238
R71	Comp, 1.5 kΩ ±5%	6099-2155	75042	BTS, 1.5 kΩ ±5%	
R72	Comp, 8.2 kΩ ±5%	6099-2825	75042	BTS, 8.2 kΩ ±5%	
R74	Comp, 4.3 kΩ ±5%	6099-2435	75042	BTS, 4.3 kΩ ±5%	
R75	Comp, 5.1 M ±5%	6099-5515	75042	BTS, 5.1 M ±5%	
R76	Pot, wire wound	6051-3209	02660	2600-PC, 20 kΩ ±10%	
R79	Comp, 2.7 kΩ ±5%	6099-2275	75042	BTS, 2.7 kΩ ±5%	
R80	Comp, 2 MΩ ±5%	6099-5205	75042	BTS, 2 MΩ ±5%	
R81	Pot., wire wound	6051-3209	02660	2600-PC, 20 kΩ ±10%	
R82	Comp, 180 kΩ ±5%	6099-4185	75042	BTS, 180 kΩ ±5%	
R83	Comp, 3 kΩ ±5%	6099-2305	75042	BTS, 3 kΩ ±5%	5905-682-4097
R84 and					
R85	Comp, 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R86	Comp, 220 Ω, ±5%	6099-1225	75042	BTS, 220 Ω ±5%	5905-683-2240
R87	Comp, 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R88	Comp, 1.8 k ±5%	6099-2185	75042	BTS, 1.8 kΩ ±5%	5905-688-3738
R89	Comp, 10 M ±5%	6099-6105	75042	BTS, 10 M ±5%	
R90	Comp, 5.1 M ±5%	6099-5515	75042	BTS, 5.1 M ±5%	
R91	Pot., wire wound	6051-3209	02660	2600-PC, 20 kΩ ±10%	
R92	Comp, 10 M ±5%	6099-6105	75042	BTS, 10 M ±5%	
R93	Comp, 15 Ω ±5%	6099-0155	75042	BTS, 15 Ω ±5%	
R94	Comp, 15 Ω ±5%, 1/4 W	6099-0155	75042	BTS, 15 Ω, ±5%	
R95 thru					
R97	Comp, 20 kΩ ±5%	6099-3205	75042	BTS, 20 kΩ ±5%	5905-686-3368
R98	Comp, 470 Ω ±5%	6100-1475	01121	RC20GF471J	5905-192-3973

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
TRANSISTORS					
Q1	Type TD-100	8210-1130	56289	TD-100	
Q2	Type 2N4384	8210-1131	56289	2N4384	
Q3	Type 2N4250	8210-1135	07263	2N4250	
Q4 and					
Q5	Type 2N5459	8210-1177	04713	2N5459	
Q6	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749
Q7	Type 2N5459	8210-1177	04713	2N5459	
Q9	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749
Q10	Type UC2138	8210-1178	61637	UC2138	
Q12	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749
Q13	Type 2N4275	8210-1126	07263	2N4275	
Q14	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749
Q16 thru					
Q21	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749

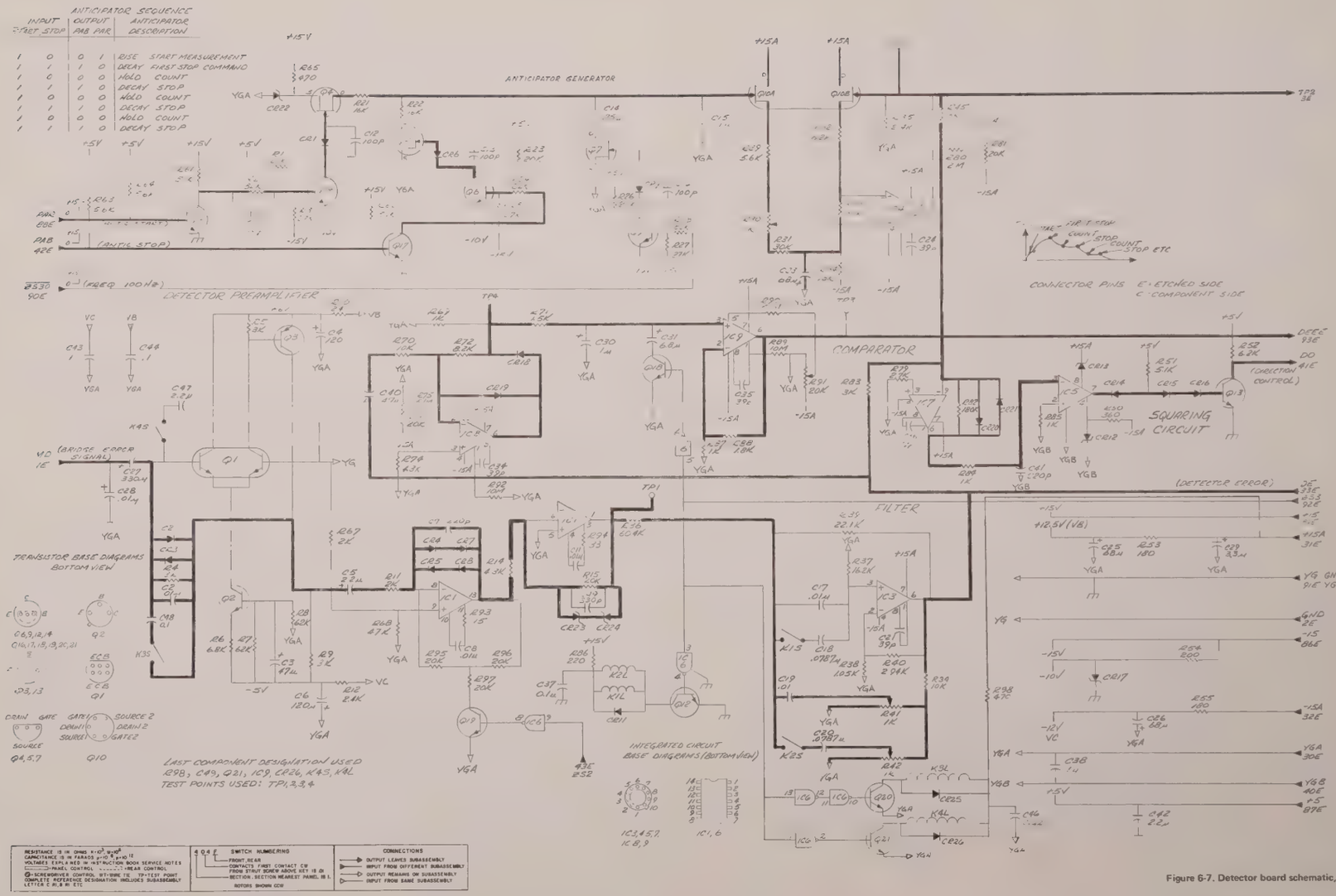

ANTICIPATOR SEQUENCE
INPUT START STOP
OUTPUT PAB PAR
ANTICIPATOR DESCRIPTION
1 0 0 1 RISE START MEASUREMENT
1 1 1 0 DELAY FIRST STOP COMMAND
1 0 0 0 HOLD COUNT
1 1 0 DECAY STOP
1 0 0 0 HOLD COUNT
1 1 1 0 DECAY STOP
1 0 0 0 HOLD COUNT
1 1 1 0 DECAY STOP
ANTICIPATOR GENERATOR
DETECTOR PREAMPLIFIER
COMPARATOR
SQUARING CIRCUIT
FILTER
TRANSISTOR BASE DIAGRAMS BOTTOM VIEW
INTEGRATED CIRCUIT BASE DIAGRAMS (BOTTOM VIEW)
LAST COMPONENT DESIGNATION USED
C98; C49, Q21, IC9, CR26, K4S, K4L
TEST POINTS USED: TP1, 2, 3, 4
CONNECTOR PINS E: ETCHED SIDE
C: COMPONENT SIDE
SWITCH NUMBERING
CONNECTIONS
OUTPUT LEAVES SUBASSEMBLY
INPUT FROM DIFFERENT SUBASSEMBLY
OUTPUT REMAINS ON SUBASSEMBLY
INPUT FROM SAME SUBASSEMBLY

Figure 6-7. Detector board schematic, D.

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
	RANGE BOARD (P/N 1683-4765) ELECTRICAL REPLACEABLE PARTS				
	CAPACITORS				
C1 and C2	Tantalum, 4.7 µF ±20%, 10 V	4450-4700	56289	150D465X0015B2	5910-813-8160
C3	Ceramic, 10000 pF +80-20%, 500 V	4406-3109	72982	811, .01 µF, +80-20%	5910-977-5779
C4	Ceramic, 1 µF ±20%	4400-2070	80183	5C13, 1 µF ±20%	5910-083-6445
	DIODES				
CR1 thru CR6	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR8 thru CR11	Type 1N3604				
CR12 and CR13	Type 1N191	6082-1008	93916	1N191	5961-296-3360
CR14 and CR15	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR16	Type 1N995	6082-1002	80368	1N995	5961-893-6762
	INDICATOR LAMPS				
DS1 thru DS8	Lamp	5600-1071	17460	2309	
	INTEGRATED CIRCUITS				
IC1	Digital	5431-9462	96214	SN15846N	
IC2	Digital	5431-9302	96214	SN15830N	
IC3	Digital	5431-9302	96214	SN15830N	
IC4	Digital	5431-9362	96214	SN15836N	
IC5	Digital	5431-9622	96214	SN15862N	
IC6	Digital	5431-9302	96214	SN15830N	
IC7	Digital	5431-9302	96214	SN15830N	
IC8	Digital	5431-9442	96214	SN15844N	
IC9	Digital	5431-9099	96214	SN158099N	
IC10	Digital	5431-9462	96214	SN15846N	
IC11	Digital	5431-9362	96214	SN15836N	
IC12	Digital	5431-9442	96214	SN15844N	
IC13	Digital	5431-9099	96214	SN158099N	
IC14	Digital	5431-9622	96214	SN15862N	
IC15	Digital	5431-9362	96214	SN15836N	
IC16	Digital	5431-9442	96214	SN15844N	
IC17	Digital	5431-9492	96214	SN15849N	
IC18	Digital	5431-9482	96214	SN15848N	
IC19	Digital	5431-9302	96214	SN15830N	
IC20	Digital	5431-9093	96214	SN158093N	
IC21	Digital	5431-9362	96214	SN15836N	
IC22	Digital	5431-9462	96214	SN15846N	
IC23	Digital	5431-9442	96214	SN15844N	
IC24	Digital	5431-9442	96214	SN15844N	
IC25	Digital	5431-9362	96214	SN15836N	
IC26	Digital	5431-9462	96214	SN15846N	
IC27	Digital	5431-9442	96214	SN15844N	
IC28 and IC29	Digital	5431-9482	96214	SN15848N	
IC30	Digital	5431-9462	96214	SN15846N	
IC31 and IC32	Digital	5431-9322	96214	SN15832N	
IC33	Digital	5431-9492	96214	SN15849N	
IC34 and IC35	Digital	5431-9322	96214	SN15832N	
IC36	Digital	5431-9462	96214	SN15846N	
	RESISTORS				
R1 and R2	Comp., 10 kΩ ±5%	6099-3105	75042	BTS, 10 kΩ ±5%	5905-683-2238
R3 and R4	Comp., 51 kΩ ±5%	6099-3515	75042	BTS, 51 kΩ ±5%	5905-682-4103
R5	Comp., 24 kΩ ±5%	6099-3245	75042	BTS, 24 kΩ ±5%	
R6	Comp., 5.6 kΩ ±5%	6099-2565	75042	BTS, 5.6 kΩ ±5%	5905-691-0195
R7	Comp., 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R8 and R9	Comp., 5.6 kΩ ±5%	6099-2565	75042	BTS, 5.6 kΩ ±5%	5905-691-0195
	TRANSISTOR				
Q1	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749

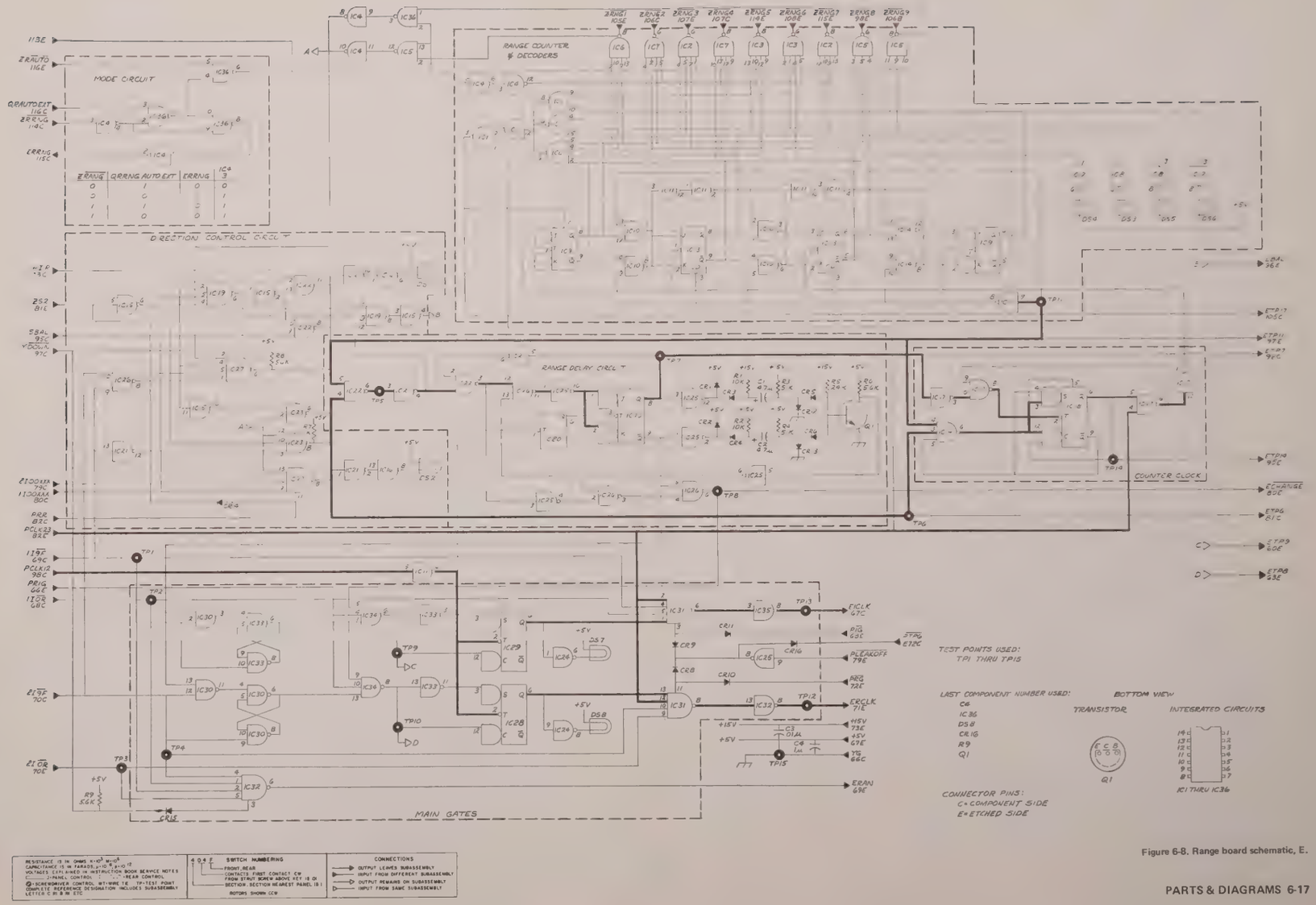
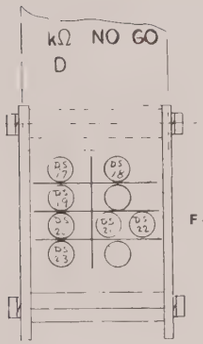


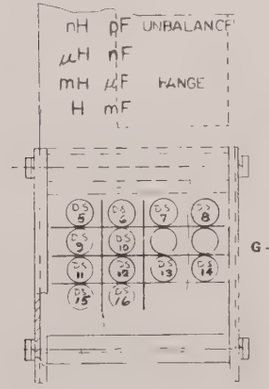
Figure 6-8. Range board schematic, E.

ELECTRICAL PARTS LIST

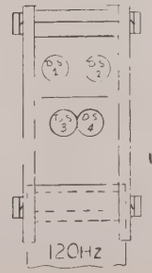
Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No
	F-DISPLAY MODULE (P/N 1683-4736) REPLACEABLE PARTS				
LAMPS					
DS17 thru DS23	Lamp	5600-1070	17460	2334	
WINDOW, MARKED		1683-7421	24655	1683-7421	
	G-DISPLAY MODULE (P/N 1683-4733) REPLACEABLE PARTS				
LAMPS					
DS5 thru DS16	Lamp	5600-1070	17460	2334	
WINDOW, MARKED		1683-7411	24655	1683-7411	
	U-DISPLAY MODULE (P/N 1683-4739) REPLACEABLE PARTS				
LAMPS					
DS1 thru DS4	Lamp	5600-4170	17460	2334	
WINDOW, MARKED		1683-7431	24655	1683-7431	



F - Display Module Assembly.



G - Display Module Assembly.



U - Display Module Assembly.

ELECTRICAL PARTS LIST (cont)

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No
	DISPLAY BOARD (P/N 1683-4760) ELECTRICAL REPLACEABLE PARTS				
DIODES					
CR1	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
INTEGRATED CIRCUITS					
IC1	Digital	5431-9362	96214	SN15836N	
IC2 thru IC5	Digital	5431-9602	07263	CμL996079	
IC6	Digital	5431-9362	96214	SN15836N	
IC7 thru IC10	Digital	5431-9602	07263	CμL996079	
IC11 thru IC14	Digital	5431-9362	96214	SN15836N	
JACKS					
J9 thru J18	Socket	7540-3466	83781	RTS-12	
RESISTORS					
R1 thru R10	Comp., 30 KΩ ±5%	6120-3305	01121	RC42G1=303J	5905-171-1977
TRANSISTORS					
Q1 thru Q11	Type 2N4410	8210-1176	04713	2N4410	

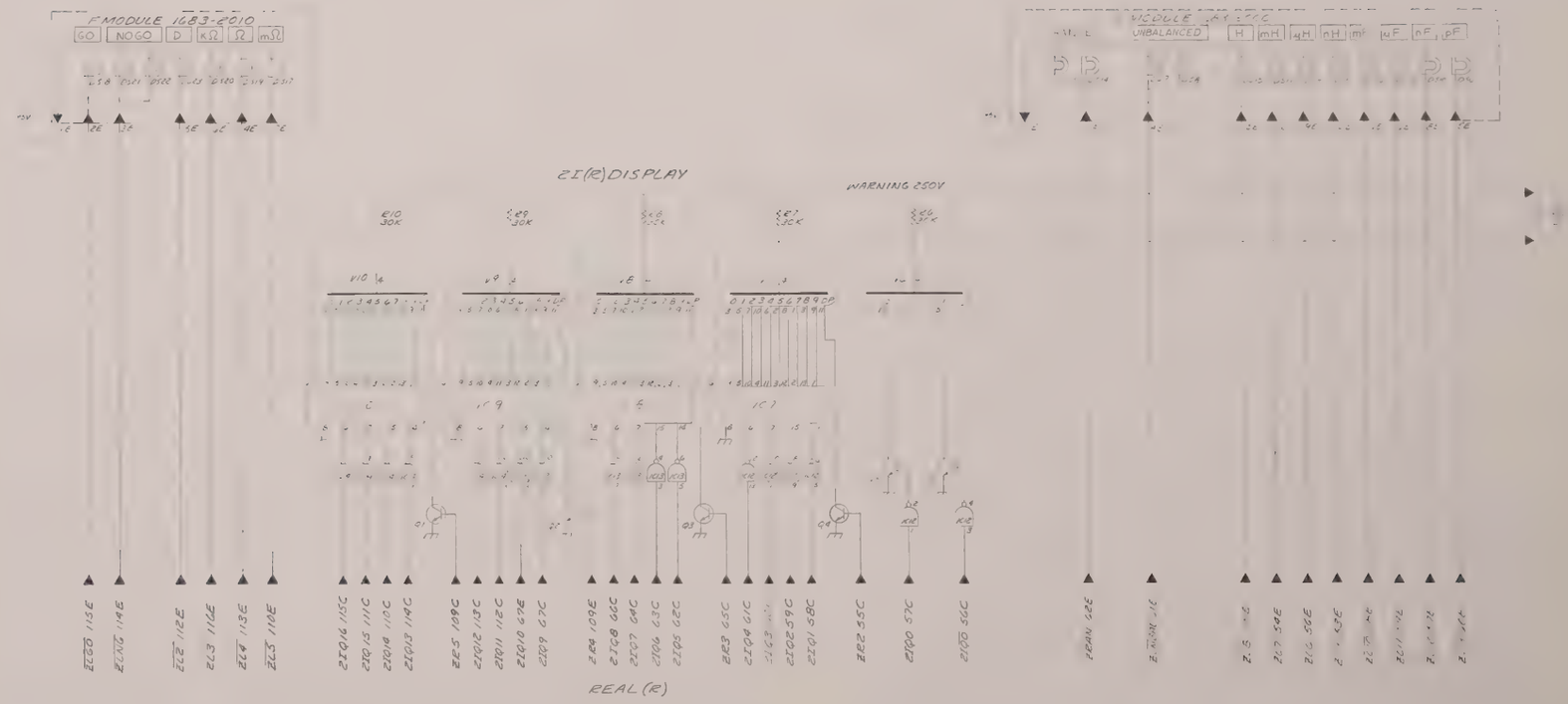


Figure 6-9. Display board schematic (sheet 1 of 2), H.

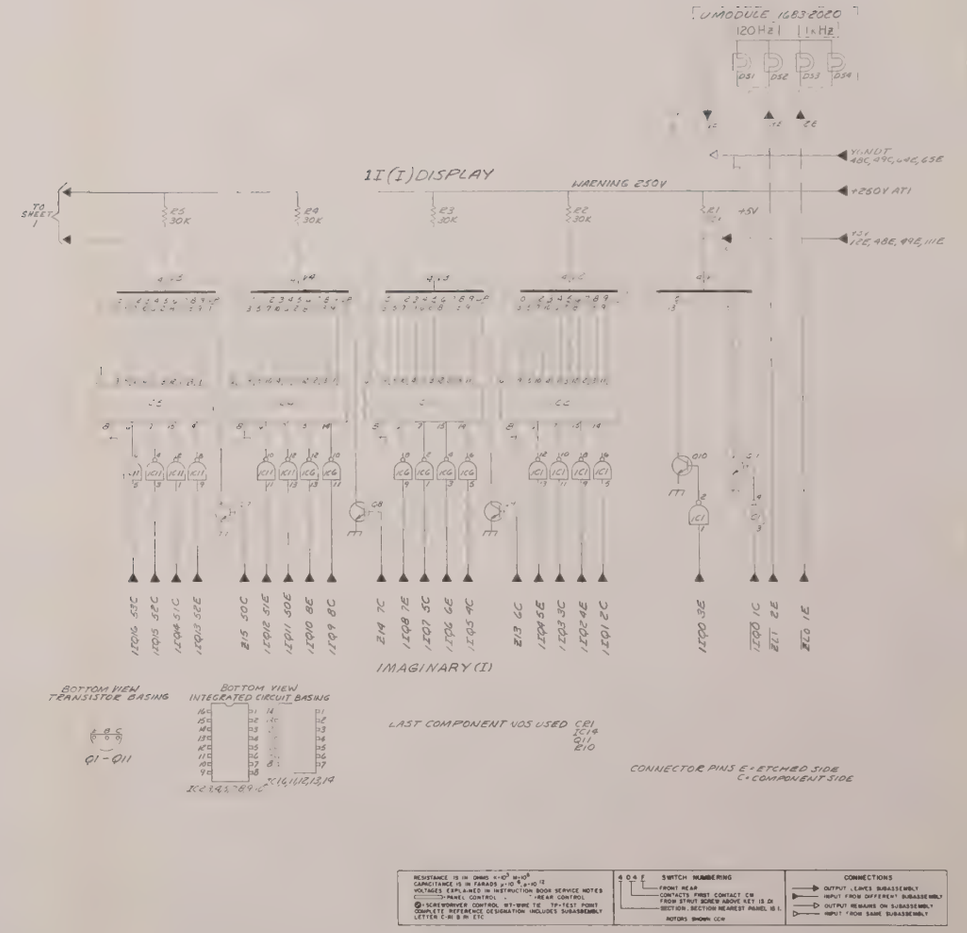


Figure 6-10. Display board schematic (sheet 2 of 2), H.

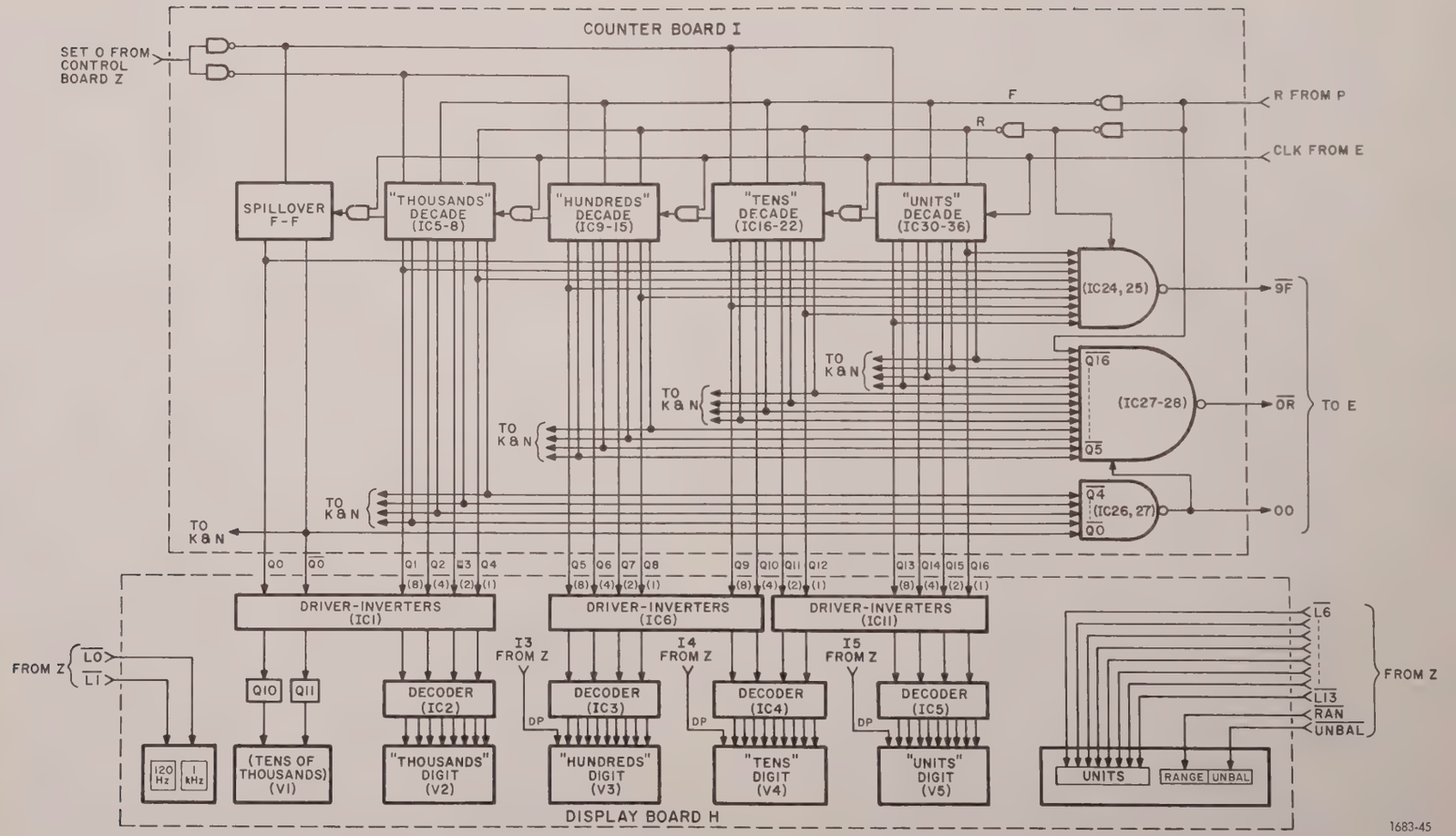


Figure 6-11. Counter and display circuit block diagram showing circuit interface.

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
	COUNTER BOARDS (11 and 21, P/N 1683-4755) ELECTRICAL REPLACEABLE PARTS				
	CAPACITORS				
C1 and C2	Ceramic 0.1 μF ±20%	4400-2050	80183	5C13, 0.1 μF ±20%	5910-080-4046
	DIODES				
CR1 thru CR3	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR4 thru CR7	Type 1N995	6082-1002	80368	1N995	5961-893-6762
	INTEGRATED CIRCUITS				
IC1	Digital	5431-9452	96214	SN15845N	
IC2	Digital	5431-9492	96214	SN15849N	
IC3	Digital	5431-9322	96214	SN15832N	
IC4	Digital	5431-9099	96214	SN158099N	
IC5 thru IC7	Type SN15846N	5431-9462	96214	SN15846N	
IC8	Type SN158099N	5431-9099	96214	SN158099N	
IC9	Type SN15849N	5431-9492	96214	SN15849N	
IC10	Type DTUL 932	5431-9322	07263	DTUL 932	
IC12 thru IC14	Type SN15846N	5431-9462	96214	SN15846N	
IC16	Type SN15849N	5431-9492	96214	SN15849N	
IC17	Type DTUL 932	5431-9322	07263	DTUL 932	
IC19 thru IC21	Type SN15846N	5431-9462	96214	SN15846N	
IC22	Digital				
IC23 and IC24	Digital	5431-9322	96214	SN15832N	
IC25	Digital	5431-9332	96214	SN15833N	
IC26	Digital	5431-9492	96214	SN15849N	
IC27	Digital	5431-9322	96214	SN15832N	
IC28	Digital	5431-9332	96214	SN15833N	
IC29	Digital	5431-9322	96214	SN15832N	
IC30	Digital	5431-9492	96214	SN15849N	
IC31	Digital	5431-9322	96214	SN15832N	
IC32	Digital	5431-9097	96214	SN158097N	
IC 33,34 and 35	Digital	5431-9462	96214	SN15846N	
IC36	Digital	5431-9097	96214	SN158097N	

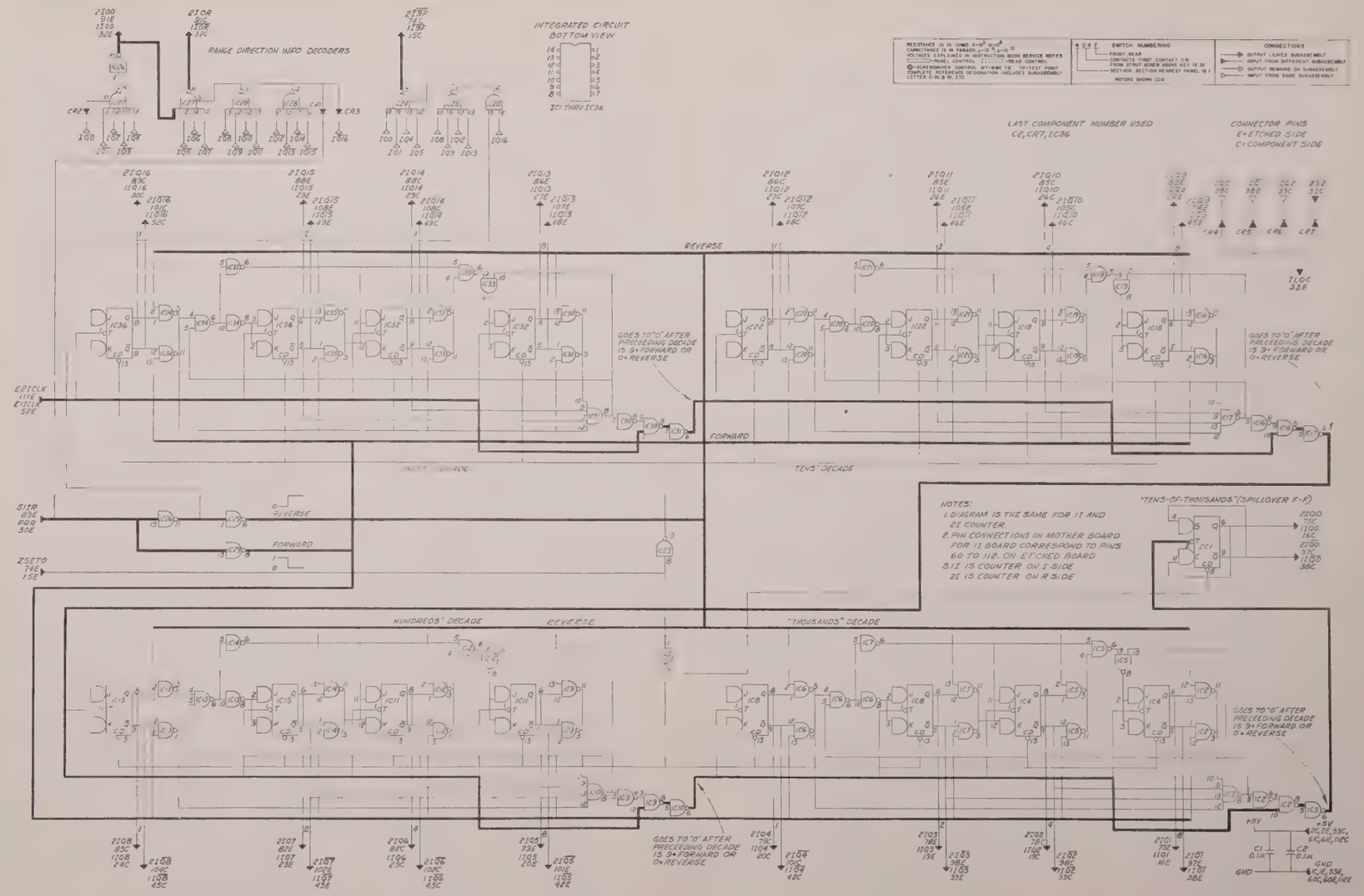
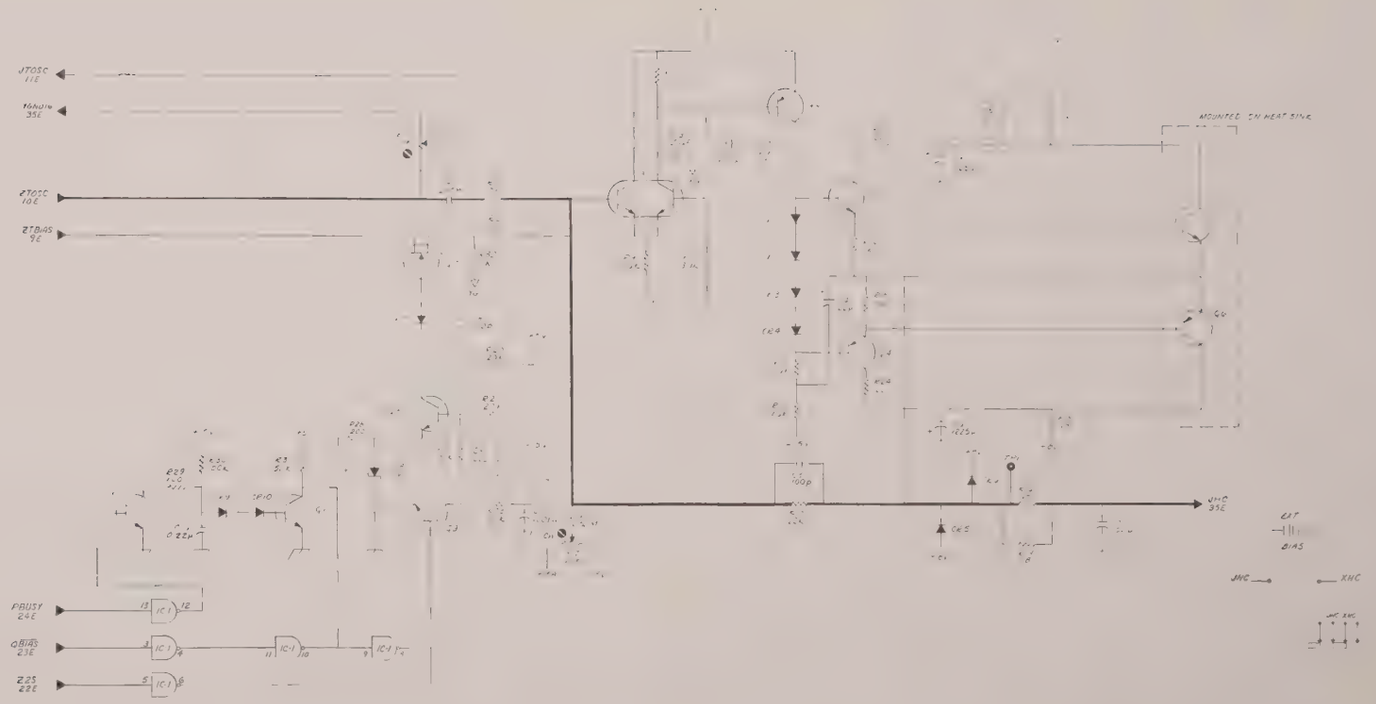
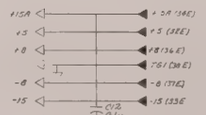

RANGE DIRECTION INFO DECODERS
INTEGRATED CIRCUIT BOTTOM VIEW
IC1 THRU IC36
LAST COMPONENT NUMBER USED C2,CR7,IC36
CONNECTOR PINS E=ETCHED SIDE C=COMPONENT SIDE
REVERSE
FORWARD
GOES TO "0" AFTER PRECEEDING DECADE IS 9+FORWARD OR 0+REVERSE
E2TCLK
E1TCLK
S1TR
Z5ETO
"TENS-OF-THOUSANDS" (SPILLOVER F-F)
NOTES:
1. DIAGRAM IS THE SAME FOR 1I AND 2I COUNTER.
2. PIN CONNECTIONS ON MOTHER BOARD FOR 1I BOARD CORRESPOND TO PINS 60 TO 112. ON ETCHED BOARD.
3.1I IS COUNTER ON I-SIDE
2I IS COUNTER ON R SIDE
"HUNDREDS" DECADE
"THOUSANDS" DECADE
+5V
GND

Figure 6-12. 1I and 2I Counter boards logic diagram, 1I and 2I.

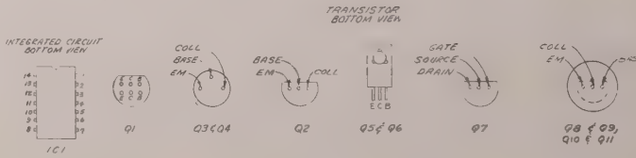
Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
	POWER AMPLIFIER BOARD (P/N 1683-4795) ELECTRICAL REPLACEABLE PARTS				
CAPACITORS					
C1	Tantalum, 68 µF ±20%	4450-5615	80183	150D686X0015R2	
C2	Ceramic, 0.001 µF +80-20%	4404-2109	72982	831, 0.001 µF +80-20%	5910-075-9607
C3	Ceramic, 100 pF, +80-20%	4404-1109	72982	831, 100 pF +80-20%	
C4	Tantalum, 22 µF ±20%	4450-5300	56289	150D226X0015B2	5910-752-4270
C5 and C6	Electrolytic, 1225 µF +150-10%	4450-6115	37942	TT, 1225 µF +150-10%	
C7	Ceramic, 0.1 µF +80-20%	4403-4100	80131	CC63, 0.1 µF +80-20%	5910-974-5699
C8 and C9	Ceramic, 100 pF +80-20%	4404-1109	72982	831, 100 pF +80-20%	
C10	Ceramic, 0.22 µF +80-20%	4432-4229	56289	29C365, 0.22 µF +80-20%	
C11	Ceramic, 0.001 µF +80-20%	4404-2109	72982	831, 0.001 µF +80-20%	5910-075-9607
C12	Ceramic, 0.1 µF +80-20%	4403-4100	80131	CC63, 0.1 µF +80-20%	5910-974-5699
C13	Ceramic, 150 pF ±10%, 500 V	4404-1158	72982	831, 150 pF, ±10%	
DIODES					
CR1 thru CR3	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR4	Type 1N695	6082-1014	24446	1N695	
CR5 and CR6	Type 1N3253	6081-1001	79089	1N3253	5961-811-8372
CR7	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR8	Type 1N758A	6083-1012	07910	1N758A	
CR9 and CR10	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
INTEGRATED CIRCUIT					
IC1	Digital	5431-9362	96214	JN15836N	
RESISTORS					
R1 and R2	Comp., 10 kΩ ±5%	6099-3105	75042	BTS, 10 kΩ ±5%	5905-683-2238
R3	Comp., 6.2 kΩ ±5%	6099-2625	75042	BTS, 6.2 kΩ ±5%	5905-682-4100
R4	Comp., 2 kΩ ±5%, 1/4 W	6099-2205	75042	BTS, 2 kΩ, ±5%	5905-686-3370
R5	Comp., 5.1 MΩ ±5%	6099-5515	75042	BTS, 5.1 MΩ ±5%	
R7	Pot., wire wound, 20 kΩ ±10%	6051-3209	02660	2600PC, 20 kΩ 10%	
R9	Comp., 56 kΩ ±5%	6099-3565	75042	BTS, 56 kΩ ±5%	5905-800-0179
R10	Comp., 3.9 kΩ ±5%	6099-2395	75042	BTS, 3.9 kΩ ±5%	
R11 and R12	Comp., 1.6 kΩ ±5%	6099-2165	75042	BTS, 1.6 kΩ ±5%	
R13	Comp., 22 kΩ ±5%	6099-3225	75042	BTS, 22 kΩ ±5%	5905-687-0002
R14 and R15	Comp., 150 Ω ±5%	6100-1155	01121	RC20GF151J	5905-299-1541
R16 thru R19	Power, wire wound, 1.8 Ω, 5 W, ±5%	6660-9185	75042	AS-5, 1.8 Ω ±5%	
R20	Comp., 20 kΩ ±5%	6099-3205	75042	BTS, 20 kΩ ±5%	5905-686-3368
R21	Comp., 27 kΩ ±5%	6099-3275	75042	BTS, 27 kΩ ±5%	5905-683-3838
R22	Comp., 82 kΩ ±5%	6099-3825	75042	BTS, 82 kΩ ±5%	
R23	Comp., 5.1 kΩ ±5%	6099-2515	75042	BTS, 5.1 kΩ ±5%	5905-683-2241
R24	Comp., 22 Ω ±5%	6100-0225	01121	RC20GF220J	5905-279-3519
R25	Power, wire wound, 1.8 Ω, 5W, ±5%	6660-9185	75042	AS-5, 1.8 Ω ±5%	
R26	Comp., 22 Ω ±5%	6100-0225	01121	RC20GF220J	5905-279-3519
R27	Pot., comp., 10 kΩ ±10%	6049-0189	80294	3009P, 10 kΩ 10%	
R28	Comp., 200 Ω ±5%	6099-1205	75042	BTS, 200 Ω ±5%	5905-683-2239
R29	Comp., 100 Ω ±5%	6099-1105	75042	BTS, 100 Ω 5%	
R30	Comp., 100 kΩ ±5%	6099-4105	75042	BTS, 100 kΩ 5%	5905-686-3129
R31	Comp., 5.1 kΩ ±5%	6099-2515	75042	BTS, 5.1 kΩ ±5%	5905-683-2241
R32	Comp., 10 kΩ ±5%, 1/4 W	6099-2105	75042	BTS, 1 kΩ, ±5%	5905-681-6422
TRANSISTORS					
Q1	Type TD-100	8210-1130	56289	TD-100	
Q2	Type 2N4125	8210-1125	04713	2N4125	
Q3	Type 2N2218	8210-1028	96214	5960-059-4464	
Q4	Type 2N2904	8210-1074	07263	2N2904	
Q5	Type 2N5190	8210-1196	04713	2N5190	
Q6	Type 2N5193	8210-1197	04713	2N5193	
Q7	Type 2N5459	8210-1177	04713	2N5459	
Q8 thru Q11	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749





LAST COMPONENT NUMBERS USED
C10, CR10, IC1, Q11, R32

CONNECTOR PINS: E = ETCHED SIDE
C = COMPONENT SIDE



RESISTANCE IS IN OHMS, K=10^3 M=10^6
CAPACITANCE IS IN FARADS μ=10^{-6} p=10^{-12}
VOLTAGES EXPLAINED IN INSTRUCTION BOOK SERVICE NOTES
—○— PANEL CONTROL
—●— SCREWDRIVER CONTROL WIT=WIRE TIE TP=TEST POINT
COMPLETE REFERENCE DESIGNATION INCLUDES SUBASSEMBLY LETTER C-IN B-IN ETC

SWITCH NUMBERING
FRONT, REAR
CONTACTS FURTHEST CONTACT CW FROM STRUT SCREW ABOVE KEY IS CR
SECTION SECTION NEAREST PANEL IS 1
ROTORS SHOWN CCW

CONNECTIONS
OUTPUT LEAVES SUBASSEMBLY
INPUT FROM DIFFERENT SUBASSEMBLY
OUTPUT REMAINS ON SUBASSEMBLY
INPUT FROM SAME SUBASSEMBLY

Figure 6-13. Power amplifier board schematic, J.

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
	K-DIVIDER BOARD (P/N 1683-4721) ELECTRICAL REPLACEABLE PARTS				
	CAPACITORS				
C3	Ceramic, .068 pF ±10% 500 V	4400-0068	78488	GA, .068 pF ±10%	
C4	Ceramic, .02 µF +80-20% 100 V	4402-3200	01121	35-203W	5910-952-8659
C5	Electrolytic, 15 µF ±20% 20 V	4450-5200	56289	150D156X0020B2	5910-855-6335
C6	Ceramic,10 pF ±5% 500 V	4404-0208	72982	831, 20 pF ±5%	
C7	Electrolytic, 68 µF ±20% 15 V	4450-5615	80183	150D686X0015R2	
C9	Ceramic, .02 µF +80-20% 100 V	4402-3200	01121	35-203W	5910-952-8659
C10	Electrolytic, 68 µF ±20% 15 V	4450-5615	80183	150D686X0015R2	
C12	Ceramic, 1000 pF +80-20% 500 V	4404-2109	72982	831, .001 µF +80-20%	5910-075-9607
C13	Ceramic, Tubular, 1.2 pF, ±10%,500 V	4400-0129	24655	4400-0129	
C16	Ceramic, 1.8 pF ±5% 500 V	4400-0180	78488	GA, 1.8 pF ±5%	
C17	Ceramic, 1.2 pF ±10% 500 V	4400-0129	78488	GA, 1.2 pF ±10%	
C22	Ceramic, 0.1 µF +80-20% 100 V	4403-4100	80183	CC63, .1 µF +80-20%	5910-811-4788
C23	Tantalum, 1000 pF, +80-20%, 20 V	4404-2109	72982	831, .001 µF, +80-20%	5910-075-9607
C24	Ceramic, 39 pF ±10% 500 V	4404-0398	72982	831, 39 pF ±10%	
	DIODES				
CR1	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR2	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR3	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR4	Type 1N695	6082-1014	24446	1N695	
CR5	Type 1N695	6082-1014	24446	1N695	
CR6	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR7	Type 1N695	6082-1014	24446	1N695	
CR8	Type 1N695	6082-1014	24446	1N695	
CR9	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR10	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR11	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR12	Type 1N695	6082-1014	24446	1N695	
CR13	Type 1N695	6082-1014	24446	1N695	
CR14	Type 1N3605	6082-1001	24446	1N3604	5961-995-2199
CR15	Type 1N695	6082-1014	24446	1N695	
CR16	Type 1N695	6082-1014	24446	1N695	
CR17	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR18	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR19	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR20	Type 1N695	6082-1014	24446	1N695	
CR21	Type 1N695	6082-1014	24446	1N695	
CR22	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR23	Type 1N695	6082-1014	24446	1N695	
CR24	Type 1N695	6082-1014	24446	1N695	
CR25	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR26	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR27	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR28	Type 1N695	6082-1014	24446	1N695	
CR29	Type 1N695	6082-1014	24446	1N695	
CR30	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR31	Type 1N695	6082-1014	24446	1N695	
CR32	Type 1N695	6082-1014	24446	1N695	
CR33	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR36	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR42	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
	INTEGRATED CIRCUITS				
IC1	Digital 936	5431-9362	07263	DTµL-936	
IC2	Linear 301A	5432-1004	12040	LM301A	
	RELAYS				
K27S	Reed switch	6090-0800	30874	76586S	
K28S	Reed switch	6090-0800	30874	76586S	
K27L	Reed coil	6090-1130	71707	XU-8242-P	
K28L	Reed coil	6090-1130	71707	XU-8242-P	
	RESISTORS				
R1	Comp, 2.7 kΩ ±5% 1/4 W	6099-2275	75042	BTS, 2.7 kΩ ±5%	
R2	Comp, 2.7 kΩ ±5% 1/4 W	6099-2275	75042	BTS, 2.7 kΩ ±5%	
R3	Comp, 2.7 kΩ ±5% 1/4 W	6099-2275	75042	BTS, 2.7 kΩ ±5%	
R4	Comp, 2.7 kΩ ±5% 1/4 W	6099-2275	75042	BTS, 2.7 kΩ ±5%	
R5	Comp, 2.7 kΩ ±5% 1/4 W	6099-2275	75042	BTS, 2.7 kΩ ±5%	
R6 thru R17	Comp, 18 kΩ ±5% 1/4 W	6099-3185	75042	BTS, 18 kΩ ±5%	

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
R18	Comp, 2.4 kΩ ±5% 1/4 W	6099-2245	75042	BTS, 2.4 kΩ ±5%	5905-683-7724
R19	Comp, 2.4 kΩ ±5% 1/4 W	6099-2245	75042	BTS, 2.4 kΩ ±5%	5905-683-7724
R20	Comp, 2.4 kΩ ±5% 1/4 W	6099-2245	75042	BTS, 2.4 kΩ ±5%	5905-683-7724
R21	Comp, 2.4 kΩ ±5% 1/4 W	6099-2245	75042	BTS, 2.4 kΩ ±5%	5905-683-7724
R22	Comp, 2.4 kΩ ±5% 1/4 W	6099-2245	75042	BTS, 2.4 kΩ ±5%	5905-683-7724
R23 thru R30	Comp, 16 kΩ ±5% 1/4 W	6099-3165	75042	BTS, 16 kΩ ±5%	
R31 thru R34	Comp, 16 kΩ ±5% 1/4 W	6099-3165	75042	BTS, 16 kΩ ±5%	
R35 thru R39	Comp, 5.1 kΩ ±5% 1/4 W	6099-2515	75042	BTS, 5.1 kΩ ±5%	5905-279-4023
R40 thru R51	Comp, 13 kΩ ±5% 1/4 W	6099-3135	75042	BTS, 13 kΩ ±5%	5905-702-4439
R52	Comp, 10 kΩ ±5% 1/4 W	6099-3105	75042	BTS, 10 kΩ ±5%	5905-683-2238
R53	Comp, 10 kΩ ±5% 1/4 W	6099-3105	75042	BTS, 10 kΩ ±5%	5905-683-2238
R54	Comp, 10 kΩ ±5% 1/4 W	6099-3105	75042	BTS, 10 kΩ ±5%	5905-683-2238
R55	Comp, 10 kΩ ±5% 1/4 W	6099-3105	75042	BTS, 10 kΩ ±5%	5905-683-2238
R56	Comp, 10 kΩ ±5% 1/4 W	6099-3105	75042	BTS, 10 kΩ ±5%	5905-683-2238
R57 thru R68	Comp, 33 kΩ ±5% 1/4 W	6099-3335	75042	BTS, 33 kΩ ±5%	
R69	Comp, 7.5 kΩ ±5% 1/4 W	6099-2755	75042	BTS, 7.5 kΩ ±5%	
R70	Comp, 7.5 kΩ ±5% 1/4 W	6099-2755	75042	BTS, 7.5 kΩ ±5%	
R71	Comp, 7.5 kΩ ±5% 1/4 W	6099-2755	75042	BTS, 7.5 kΩ ±5%	
R72	Comp, 7.5 kΩ ±5% 1/4 W	6099-2755	75042	BTS, 7.5 kΩ ±5%	
R73	Comp, 7.5 kΩ ±5% 1/4 W	6099-2755	75042	BTS, 7.5 kΩ ±5%	
R74 thru R85	Comp, 33 kΩ ±5% 1/4 W	6099-3335	75042	BTS, 33 kΩ ±5%	
R86	Wire wound, 40 kΩ ±.01%, 1 W	6983-5011	24655	6983-5011	
R88	Wire wound, 80 kΩ ±.01%, 1 W	6983-5015	24655	6983-5015	
R89	Precision wire wound, 40 kΩ .01%	6983-5011	24655	6983-5011	
R90	Precision wire wound, 40 kΩ .01%	6983-5011	24655	6983-5011	
R91	Precision wire wound, 40 kΩ .01%	6983-5011	24655	6983-5011	
R92	Precision wire wound, 16.0012 kΩ ±.01% 1/2 W	6982-5008	24655	6982-5008	
R93	Precision wire wound, 13.333 kΩ ±.01% 1/2 W	6982-5009	24655	6982-5009	
R94	Precision wire wound, 13.333 kΩ ±.01% 1/2 W	6982-5009	24655	6982-5009	
R96	Precision wire wound, 160 kΩ ±.1%	6983-6011	24655	6983-6011	
R97	Precision wire wound, 80 kΩ ±.1%	6983-5012	24655	6983-5012	
R98	Precision wire wound, 80 kΩ ±.1%	6983-5012	24655	6983-5012	
R99	Precision wire wound, 80 kΩ ±.01%	6983-5015	24655	6983-5015	
R100	Precision wire wound, 32.002 kΩ ±.1%	6983-5013	24655	6983-5013	
R101	Precision wire wound, 204.48 kΩ ±.1%	6983-6010	24655	6983-6010	
R102	Precision wire wound, 204.48 kΩ ±.1%	6983-6010	24655	6983-6010	
R103	Film, 200 kΩ ±1%	6250-3200	75042	CEA, 200 kΩ ±1%	
R104	Film, 200 kΩ ±1%	6250-3200	75042	CEA, 200 kΩ ±1%	
R105	Film, 200 kΩ ±1%	6250-3200	75042	CEA, 200 kΩ ±1%	
R106	Film, 200 kΩ ±1%	6250-3200	75042	CEA, 200 kΩ ±1%	
R107	Film, 200 kΩ ±1%	6250-3200	75042	CEA, 200 kΩ ±1%	
R108	Film, 79.6 kΩ ±.5%	6351-2796	75042	CEB-TO, 79.6 kΩ ±.5%	
R109	Film, 2.21 MΩ ±1%	6350-4221	75042	CEB, 2.21 MΩ ±1%	
R110	Film, 2.15 MΩ ±1%	6350-4215	75042	CEB, 2.15 MΩ ±1%	
R112	Comp., 200 kΩ ±5%	6099-4205	75042	BTS, 200 kΩ ±5%	5905-681-8821
R113	Comp., 200 kΩ ±5%	6099-4205	75042	BTS, 200 kΩ ±5%	5905-681-8821
R114	Comp., 200 kΩ ±5%	6099-4205	75042	BTS, 200 kΩ ±5%	5905-681-8821
R115	Comp., 200 kΩ ±5%	6099-4205	75042	BTS, 200 kΩ ±5%	5905-681-8821
R116	Comp., 200 kΩ ±5%	6099-4205	75042	BTS, 200 kΩ ±5%	5905-681-8821
R117	Comp., 82 kΩ ±5%	6099-3825	75042	BTS, 82 kΩ ±5%	
R118	Comp., 22 MΩ ±5%	6099-6225	75042	BTS, 22 MΩ ±5%	
R119	Comp., 20 MΩ ±5%	6099-6225	75042	BTS, 22 MΩ ±5%	
R120					
R121	Precision wire wound,38.755kΩ±.01%1W	6983-5034	24655	6983-5034	
R122					
R124	Pot. Comp., 100 kΩ ±10%	6049-0192	80294	3009-P-1-501, 100 kΩ ±10%	
R125	Comp., 6.2 kΩ ±5% 1/4 W	6099-2625	75042	BTS, 6.2 kΩ ±5%	5905-682-4100
R126	Comp., 130 Ω ±5% 1/4 W	6099-1135	75042	BTS, 130 Ω ±5%	5905-807-6269
R127	Comp., 51 kΩ ±5% 1/4 W	6099-3515	75042	BTS, 51 kΩ ±5%	5905-200-6731
R128	Comp., 22 kΩ ±5% 1/4 W	6099-3225	75042	BTS, 22 kΩ ±5%	5905-687-0002
R129	Comp., 51 kΩ ±5% 1/4 W	6099-3515	75042	BTS, 51 kΩ ±5%	5905-200-6731
R130					
R131	Comp., 750 Ω ±5% 1/4 W	6099-1755	75042	BTS, 750 Ω ±5%	
R132	Comp., 180 Ω ±5% 1/4 W	6099-1185	75042	BTS, 180 Ω ±5%	5905-279-5476
R133					
R134	Comp., 680 Ω ±5% 1/4 W	6099-1685	75042	BTS, 680 Ω ±5%	

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
R135	Comp., 240 Ω ±5% 1/4 W	6099-1245	75042	BTS, 240 Ω ±5%	
R136	Comp., 240 Ω ±5% 1/4 W	6099-1245	75042	BTS, 240 Ω ±5%	
R137	Comp., 470 Ω ±5% 1/4 W	6099-1475	75042	BTS, 470 Ω ±5%	5905-683-2242
R138	Comp., 10 kΩ ±5% 1/4 W	6099-3105	75042	BTS, 10 kΩ ±5%	5905-683-2238
R139	Comp., 30 kΩ ±5% 1/4 W	6099-3305	75042	BTS, 30 kΩ ±5%	5905-803-2908
	TRANSISTORS				
Q1 thru Q16	Type 2N4125	8210-1125	93916	2N4125	
Q17	Type 2N4125	8210-1125	93916	2N4125	
Q18	Type 2N4125	8210-1174	24655	8210-1174	
Q19	Type 2N4125	8210-1174	24655	8210-1174	
Q20	Type 2N4125	8210-1174	24655	8210-1174	
Q21	Type 2N4125	8210-1174	24655	8210-1174	
Q22	Type 2N4125	8210-1174	24655	8210-1174	
Q23	Type 2N1302	8210-1018	96214	2N1302	5960-086-0039
Q24	Type 2N1302	8210-1018	96214	2N1302	5960-086-0039
Q25	Type 2N1302	8210-1018	96214	2N1302	5960-086-0039
Q26	Type 2N1302	8210-1018	96214	2N1302	5960-086-0039
Q27	Type 2N1302	8210-1018	96214	2N1302	5960-086-0039
Q28	Type 2N1302	8210-1018	96214	2N1302	5960-086-0039
Q29	Type 2N1302	8210-1018	96214	2N1302	5960-086-0039
Q30	Type 2N1302	8210-1018	96214	2N1302	5960-086-0039
Q31	Type 2N1302	8210-1018	96214	2N1302	5960-086-0039
Q32	Type 2N1302	8210-1018	96214	2N1302	5960-086-0039
Q33	Type 2N1302	8210-1018	96214	2N1302	5960-086-0039
Q34	Type 2N1302	8210-1018	96214	2N1302	5960-086-0039
Q35	Type 2N1302	8210-1081	01295	GA2390	
Q36	Type 2N1302	8210-1081	01295	GA2390	
Q37	Type 2N1302	8210-1081	01295	GA2390	
Q38	Type 2N1302	8210-1081	01295	GA2390	
Q39	Type 2N1302	8210-1081	01295	GA2390	
Q40	Type 2N1303	8210-1019	96214	2N1303	
Q41	Type 2N1303	8210-1019	96214	2N1303	
Q42	Type 2N1303	8210-1019	96214	2N1303	
Q43	Type 2N1303	8210-1019	96214	2N1303	
Q44	Type 2N1303	8210-1019	96214	2N1303	
Q45	Type 2N1303	8210-1019	96214	2N1303	
Q46	Type 2N1303	8210-1019	96214	2N1303	
Q47	Type 2N1303	8210-1019	96214	2N1303	
Q48	Type 2N1303	8210-1019	96214	2N1303	
Q49	Type 2N1303	8210-1019	96214	2N1303	
Q50	Type 2N1303	8210-1019	96214	2N1303	
Q51	Type 2N1303	8210-1019	96214	2N1303	
Q52	Type TD-100	8210-1130	56289	TD-100	
Q53					
Q54	Type 2N3414	8210-1047	24446	2N3414	5961-989-2749
Q55	Type 2N4250	8210-1135	93916	2N4250	
Q56	Type 2N5249	8210-1077	24454	2N3390	
Q57					
Q58					
Q59	Type 2N3414	8210-1047	24446	2N3414	5961-989-2749
Q60	Type 2N3414	8210-1047	24446	2N3414	5961-989-2749

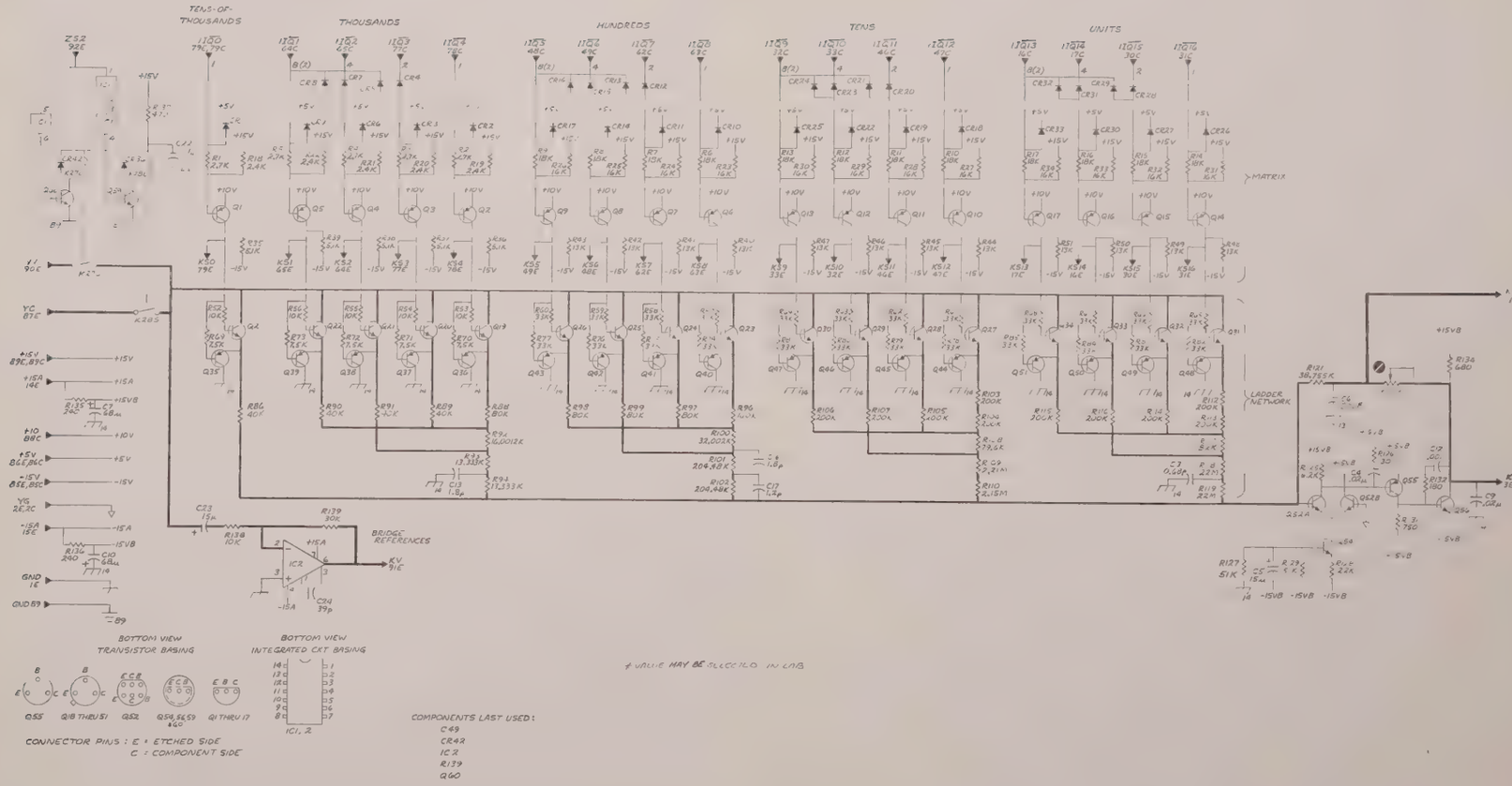


Figure 6-14. K-divider board schematic, K.

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
	LEAKAGE - CURRENT BOARD (P/N 1683-4724) ELECTRICAL REPLACEABLE PARTS				
CAPACITORS					
C1 and					
C2	Ceramic, 39 µF 10%	4404-0398	72982	831, 39 µF 10%	
C3	Tantalum, 120 µF 20%	4450-5616	56289	150D127X0010R2	
C4	Tantalum, 10 µF 20%	4450-5100	56289	150D106X0020B2	5910-855-6343
C5	Plastic, 1 µF ±10%, 200 V	4860-8275	84411	663UW, 1 µF 10%	
C6	Plastic, 0.1 µF ±10% 400 V	4860-7886	84411	663UW, 0.1 µF 10%	
C7	Plastic, 0.01 µF ±10% 100 V	4860-7750	84411	663UW, 0.01 µF 10%	
C8	Ceramic, 39 µF 10%	4404-0398	72982	831, 39 µF 10%	
C9	Ceramic, 0.01 µF +80-20%	4401-3100	80131	CC61, 0.01 µF +80-20%	5910-974-5697
C10	Ceramic, 100 pF 10%	4404-1108	72982	831, 100 pF 10%	
C11	Ceramic, 10 pF 10%	4400-1100	78488	GA, 10 pF 10%	5910-668-5861
C12	Ceramic, 0.1 µF +80-20%	4403-4100	80131	CC63, 0.1 µF +80-20%	5910-974-5699
C13	Ceramic, 1 µF 20%	4400-2070	80183	5C13, 1 µF 20%	5910-083-6445
DIODES					
CR1 thru					
CR4	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR7	Type 1N748A	6083-1002	07910	1N748A	5960-800-3973
CR8	Type 1N753A	6083-1006	07910	1N753A	5961-752-6121
CR9	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR10 and					
CR11	Type 1N645	6082-1016	24446		5961-087-6047
CR12	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR13 and					
CR14	Type 1N3604	6082-1002	80368	1N995	5961-893-6762
INTEGRATED CIRCUITS					
IC1	Linear	5432-1004	12040	LM301A	
IC2	Linear	5432-7101	07263	U5B771039X	
IC3 and					
IC4	Digital	5431-9362	96214	SN15836N	
IC5	Digital	5431-9462	96214	SN15846N	
IC6	Digital	5431-9452	96214	SN15845N	
RELAYS					
K1S thru					
K3S	Reed switch	6090-0800	30874	76586S	
K1L thru					
K3L	Reed coil	6090-1130	71707	XU-8242-P	
RESISTORS					
R1	Comp., 100 Ω ±1%	6350-0100	75042	CEB, 100 Ω 1%	5905-538-3258
R2	Comp., 1 kΩ ±1%	6250-1100	75042	CEA, 1 kΩ 1%	5905-581-6915
R3	Comp., 10.1 kΩ ±1%	6350-2101	75042	CEB, 10.1 kΩ 1%	
R4	Comp., 110 kΩ ±1%	6450-3110	75042	CEC, 110 kΩ 1%	
R5	Comp., 5.1 MΩ ±5%	6099-5515	75042	BTS, 5.1 MΩ 5%	
R6	Pot., wire wound	6051-3209	02660	2600PC, 20 kΩ 10%	
R7	Comp., 75 kΩ ±5%	6099-3755	75042	BTS, 75 kΩ 5%	
R8	Comp., 10 MΩ ±5%	6099-6105	75042	BTS, 10 MΩ 5%	
R9	Comp., 1.50 Ω ±1%	6250-0150	75042	CEA, 1.50 Ω 1%	
R10	Comp., 42.2 kΩ ±1%	6450-2422	75042	CEC, 42.2 kΩ 1%	
R11	Comp., 10.5 kΩ	6250-2105	75042	CEA, 10.5 kΩ 1%	5905-882-0037
R12	Comp., 100 kΩ ±5%	6099-4105	75042	BTS, 100 kΩ 5%	5905-686-3129
R14	Pot., wire wound, 20 kΩ ±10%	6051-3209	02660	2600PC, 20 kΩ 10%	
R16	Comp., 100 Ω ±5%	6099-1105	75042	BTS, 100 Ω 5%	
R17	Comp., 100 kΩ ±5%	6099-4105	75042	BTS, 100 kΩ 5%	5905-686-3129
R18	Comp., 220 Ω ±5%	6099-1225	75042	BTS, 220 Ω 5%	5905-683-2240
R19	Comp., 300 Ω ±5%	6099-1305	75042	BTS, 300 Ω 5%	5905-279-5481
R20	Comp., 1 MΩ ±1%	6250-4100	75042	CEA, 1MΩ 1%	5905-646-5678
R21	Comp., 5.6 kΩ ±5%	6099-2565	75042	BTS, 5.6 kΩ 5%	5905-691-0195
R22	Comp., 47 kΩ ±5%	6099-3475	75042	BTS, 47 kΩ 5%	5905-683-2246
R23	Comp., 15 kΩ ±5%	6099-3155	75042	BTS, 15 kΩ 5%	5905-681-8818
R24	Comp., 5.6 kΩ ±5%	6099-2565	75042	BTS, 5.6 kΩ 5%	5905-691-0195
R25	Comp., 47 kΩ ±5%	6099-3475	75042	BTS, 47 kΩ 5%	5905-683-2246
R26	Comp., 15 kΩ ±5%	6099-3155	75042	BTS, 15 kΩ 5%	5905-681-8818
R27	Wire wound, 1 Ω 10%	6760-9109	75042	BWH, 1Ω 10%	
R28	Comp., 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R29	Pot., wire wound	6051-3209	02660	2600PC, 20 kΩ 10%	
R30	Comp., 5.1 MΩ ±5%	6099-5515	75042	BTS, 5.1 MΩ 5%	
R31	Comp. 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R32	Comp. 5.6 kΩ ±5%	6099-2565	75042	BTS, 5.6 kΩ ±5%	5905-691-0195
R33	Comp. 200 kΩ ±5%	6099-4205	75042	BTS, 200 kΩ ±5%	5905-681-8821
TRANSISTORS					
Q1 and					
Q2	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749
Q3 and					
Q4	Type 2N4125	8210-1125	04713	2N4125	
Q5	Type TIS-74	8210-1202	96214	TIS-74	
Q6	Type 2N5459	8210-1177	04713	2N5459	
Q7	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749
Q8	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749

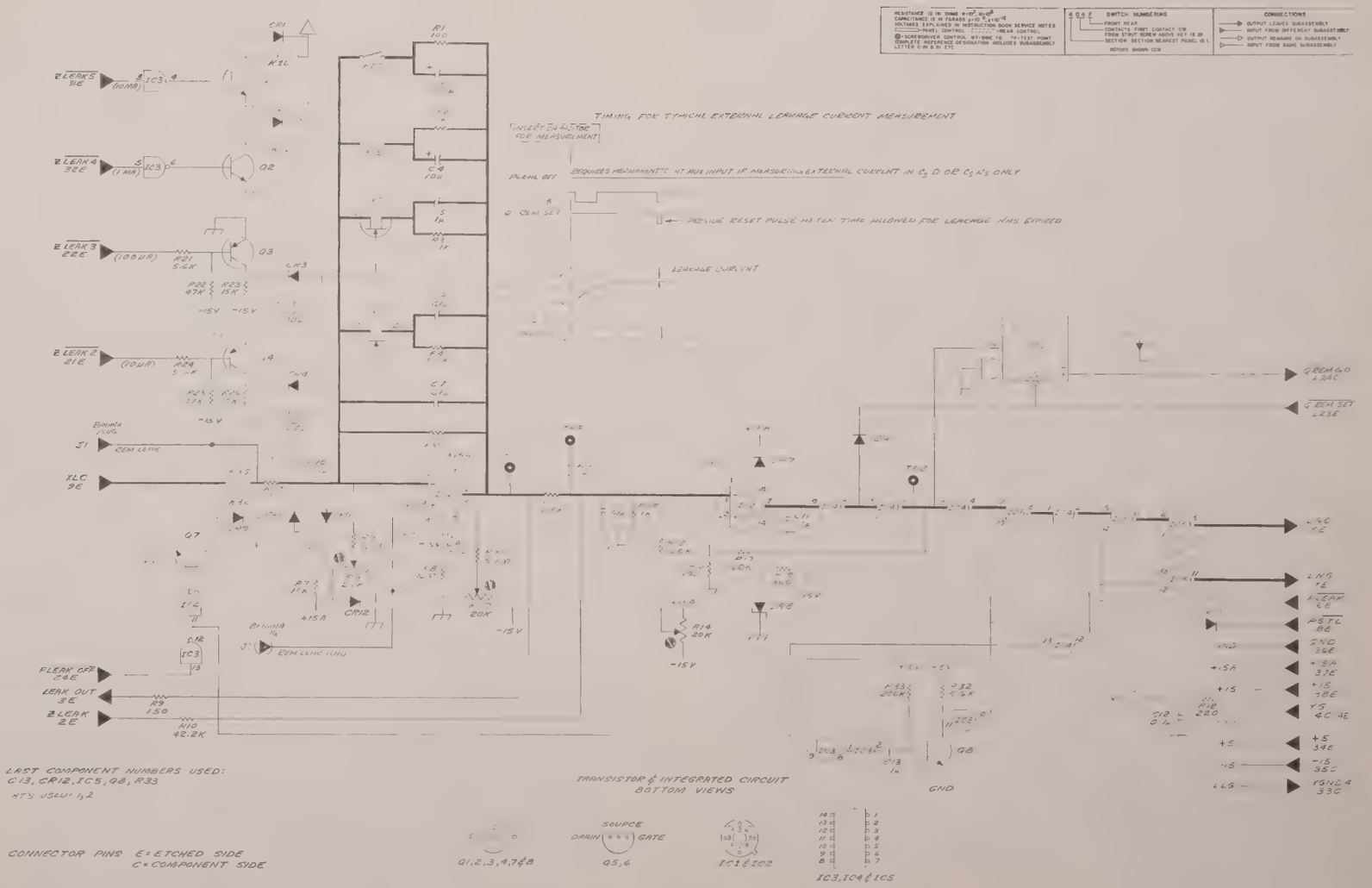
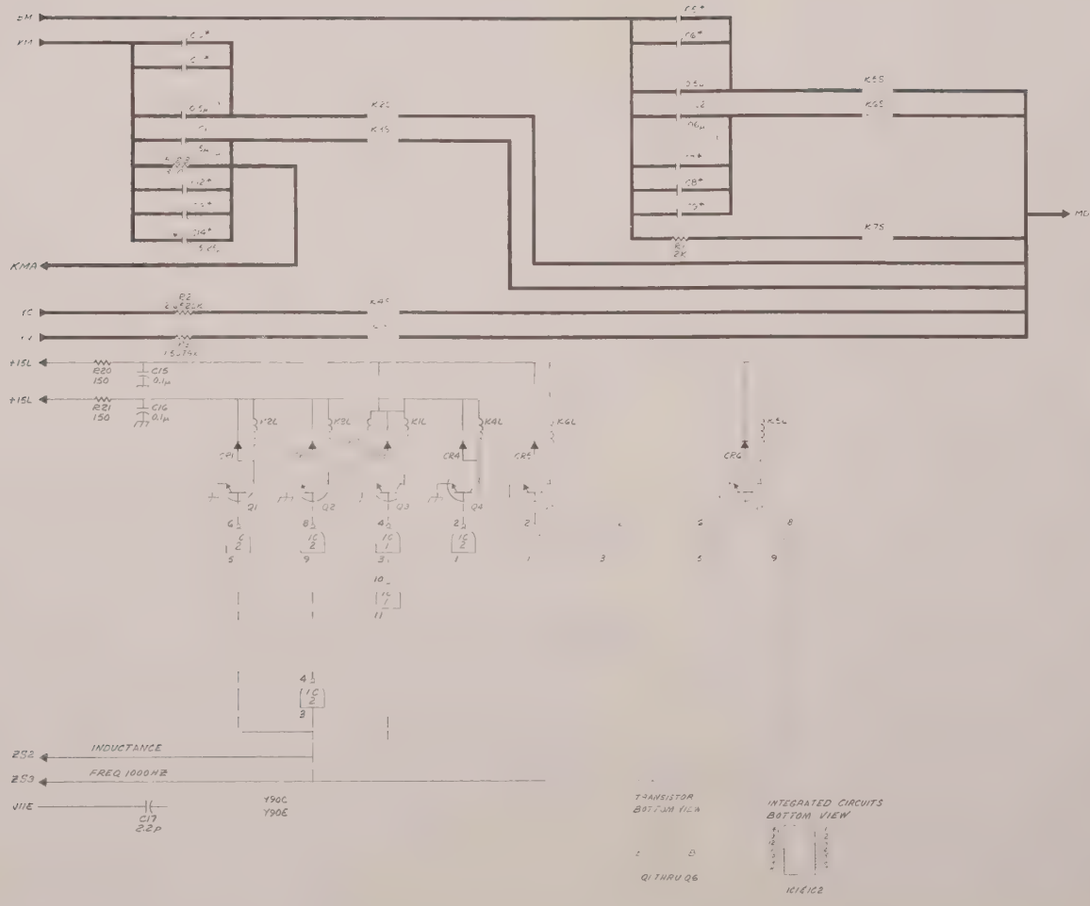


Figure 6-15. Leakage-current board schematic, L.

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
	MOTHER BOARD (P/N 1683-4706) ELECTRICAL REPLACEABLE PARTS				
CAPACITORS					
C1	Plastic, standard	4872-5000	24655	4872-5000	
C2	Plastic, standard	4872-5001	24655	4872-5001	
C5 thru C13	GR selected				
C14	Trimmer, Ceramic, 5-25 pF	4910-1150	72982	557-051, U2PO	
C15 and C16	Ceramic, 1 μF +80-20%	4403-4100	80131	CC63, .1 μF +80-20%	5910-974-5699
C17	Ceramic, 2.2 pF ±10%	4400-0200	78488	GA, 2.2 pF ±10%	
DIODES					
CR1 thru CR6	Type IN3604	6082-1001	24446	IN3604	5961-995-2199
INTEGRATED CIRCUITS					
IC1 and IC2	Digital	5431-9362	96214	SN15836N	
RESISTORS					
R1	Wire wound 2 kΩ ±.01%	6983-4036	24655	6983-4036	
R2	Wire wound 2.6526 kΩ ±.01%	6983-4037	24655	6983-4037	
R3	Wire wound 1.5079 kΩ ±.01%	6983-4038	24655	6983-4038	
R20 and R21	Comp., 150 Ω ±5%	6099-1155	75042	BTS, 150 Ω ±5%	
R123	Wire wound, 1300 Ω ±5%	6982-3000	24655	6982-3000	
RELAYS (COILS)					
K1L thru K7L	Relay	6090-1130	71707	XU-8242-P	
RELAYS (SWITCHES)					
K1S thru K7S	Relay	6090-0800	30874	76586S	
TRANSISTORS					
Q1 thru Q6	Type 2N3414	8210-1047	24446	2N3414	5961-989-2749



MOTHER BOARD RELAY SWITCHING

FUNCTION	LOGIC SIGNALS		RELAYS						
	Z52	Z53	K1	K2	K3	K4	K5	K6	K7
L1R2 120Hz	1	0	1	1	0	0	0	0	1
L2R2 1KHz	1	1	1	0	1	0	0	0	1
C1D 120Hz	0	0	0	1	0	1	1	0	0
C2D 1K Hz	0	1	0	0	1	1	0	1	0
C1E2 120Hz	0	0	0	1	0	1	1	0	0
C2R2 1K Hz	0	1	0	0	1	1	0	1	0
			A1 SWITCHES IN:						
			G_T (R3)	C_S (C1)	C_S (C1)	G_B (R2)	C_B (C2)	C_B (C2)	G_S (R1)
				C10	C12		C5	C7	
				C11	C13		C6	C8	
					C14			C9	

FOR RELAYS: 1: CLOSED (ENERGIZED)
0: OPENED (DE-ENERGIZED)

LAST COMPONENT NUMBER USED:
C17
CR6
IC2
Q2
R21

CONNECTOR PINS: E: ETCHED SIDE
C: COMPONENT SIDE

* VALUE & TYPE NO. TO BE DETERMINED BY LAB

TRANSISTOR BOTTOM VIEW

Q1 THRU Q6

INTEGRATED CIRCUITS BOTTOM VIEW

IC1 & IC2

RESISTANCE IS IN OHMS K=10^3 M=10^6
CAPACITANCE IS IN FARADS μ=10^{-6} p=10^{-12}
VOLTAGES EXPLAINED IN INSTRUCTION BOOK SERVICE NOTES
⊢⊣ = PANEL CONTROL ⊢⊣ = REAR CONTROL
S = SCANSWITCH CONTROL WIT=WIRE TIE TP=TEST POINT
COMPLETE REFERENCE DESIGNATION INCLUDES SUBASSEMBLY LETTER C IN B M ETC

4 0 6 F SWITCH NUMBERING
F = FRONT REAR
6 = CONTACTS FIRST CONTACT CW FROM STRUT SCREW ABOVE KEY 13 OR SECTION, SECTION NEAREST PANEL IS 1
0 = ROTORS SHOWN CCW
4 = SECTION

CONNECTIONS
OUTPUT LEAVES SUBASSEMBLY
INPUT FROM DIFFERENT SUBASSEMBLY
OUTPUT REMAINS ON SUBASSEMBLY
INPUT FROM SAME SUBASSEMBLY

Figure 6-16. Mother board schematic, M.

ELECTRICAL PARTS LIST

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
	DATA-OUTPUT BOARD (HI-LEVEL, P/N 1683-4703) REPLACEABLE PARTS				
	CAPACITORS				
C1 and C2	Ceramic, .001 μF +80-20%	4404-2109	72982	831, .001 μF +80-20%	5910-075-9607
C3 and C4	Ceramic, 0.1 μF +80-20%	4403-4100	80131	CC63, .1 μF +80-20%	5910-974-5699
C5	Ceramic, .01 μF +80-20%	4401-3100	80131	CC61, .01 μF +80-20%	5910-974-5697
C6	Ceramic, .1 μF ±20%	4400-2070	80183	5C13, 1 μF ±20%	5910-083-6445
	DIODES				
CR1 thru CR4	Type IN3604	6082-1001	24446	IN3604	5961-995-2199
	INTEGRATED CIRCUITS				
IC1	Linear	5432-7101	07263	U5B771039X	
IC2	Digital	5431-9112	07263	DTμL-9112	
IC3	Digital	5431-9362	07263	DTμL-936	
IC4 thru IC6	Digital	5431-9112	07263	DTμL-9112	
IC7 and IC8	Digital	5431-9302	07263	DTμL-930	
IC9 thru IC11	Digital	5431-9112	07263	DTμL-9112	
IC12	Digital	5431-9462	07263	DTμL-946	
	RESISTORS				
R1	Comp., 24 kΩ ±5%	6099-3245	75042	BTS, 24 kΩ ±5%	
R2 and R3	Comp., 9.1 kΩ ±5%	6099-2915	75042	BTS, 9.1 kΩ ±5%	
R4	Comp., 20 kΩ ±5%	6099-3205	75042	BTS, 20 kΩ ±5%	5905-686-3368
R5 and R6	Comp., 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R7	Comp., 270 kΩ ±5%	6099-1275	75042	BTS, 270 kΩ ±5%	
R8 and R9	Comp., 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R10	Comp., 2.4 kΩ ±5%	6099-2245	75042	BTS, 2.4 kΩ ±5%	5905-683-7724
R11	Comp., 51 kΩ ±5%	6099-0515	75042	BTS, 51 kΩ ±5%	
R13	Comp., 15 kΩ ±5%	6099-3155	75042	BTS, 15 kΩ ±5%	5905-681-8818
R14	Comp., 20 kΩ ±5%	6099-3205	75042	BTS, 20 kΩ ±5%	5905-686-3368
R15	Comp., 3 kΩ ±5%	6099-2305	75042	BTS, 3 kΩ ±5%	5905-682-4097
R16	Comp., 5.6 kΩ ±5%	6099-2565	75042	BTS, 5.6 kΩ ±5%	5905-691-0195
R17	Comp., 10 kΩ ±5%	6099-3105	75042	BTS, 10 kΩ ±5%	5905-683-2238
R18	Comp., 100 kΩ ±5%	6099-1105	75042	BTS, 100 kΩ ±5%	
R19	Comp., 5.6 kΩ ±5%	6099-2565	75042	BTS, 5.6 kΩ ±5%	5905-691-0195
	TRANSISTORS				
Q1 thru Q3	Type 2N3414	8210-1047	24446	2N3414	5961-989-2749

ELECTRICAL PARTS LIST (cont)

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
	DATA-OUTPUT BOARD (LO-LEVEL, P/N 1683-4704) ELECTRICAL REPLACEABLE PARTS				
	CAPACITORS				
C1 and C2	Ceramic, .001 μF +80-20%	4404-2109	72982	831, .001 μF +80-20%	5910-075-9607
C3 and C4	Ceramic, 0.1 μF +80-20%	4403-4100	80131	CC63, .1 μF +80-20%	5910-974-5699
C5	Ceramic, .01 μF +80-20%	4401-3100	80131	CC61, .01 μF +80-20%	5910-974-5697
C6	Ceramic, 1 μF, ±20%, 50 V	4400-2070	80183	5C13, 1 μF, ±20%	5910-083-6445
	DIODES				
CR1 thru CR4	Type IN3604	6082-1001	24446	IN3604	5961-995-2199
	INTEGRATED CIRCUITS				
IC1	Linear	5432-7101	07263	U5B771039X	
IC2	Digital	5431-9608	07263	TTμL-9016	
IC3	Digital	5431-9362	07263	DTμL-936	
IC4 thru IC6	Digital	5431-9608	07263	TTμL-9016	
IC7 and IC8	Digital	5431-9302	07263	DTμL-930	
IC9 thru IC11	Digital	5431-9608	07263	TTμL-9016	
IC12	Digital	5431-9462	07263	DTμL-946	
	RESISTORS				
R1	Comp., 24 kΩ ±5%	6099-3245	75042	BTS, 24 kΩ ±5%	
R2 and R3	Comp., 9.1 kΩ ±5%	6099-2915	75042	BTS, 9.1 kΩ ±5%	
R4	Comp., 20 kΩ ±5%	6099-3205	75042	BTS, 20 kΩ ±5%	5905-686-3368
R5 and R6	Comp., 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R7	Comp., 270 Ω ±5%	6099-1275	75042	BTS, 270 kΩ ±5%	
R8 and R9	Comp., 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R10	Comp., 2.4 kΩ ±5%	6099-2245	75042	BTS, 2.4 kΩ ±5%	5905-683-7724
R11	Comp., 51 Ω ±5%	6099-0515	75042	BTS, 51 kΩ ±5%	
R12	Comp., 15 kΩ ±5%	6099-3155	75042	BTS, 15 kΩ ±5%	5905-681-8818
R14	Comp., 20 kΩ ±5%	6099-3205	75042	BTS, 20 kΩ ±5%	5905-686-3368
R15	Comp., 3 kΩ ±5%	6099-2305	75042	BTS, 3 kΩ ±5%	5905-682-4097
R16	Comp., 5.6 kΩ ±5%	6099-2565	75042	BTS, 5.6 kΩ ±5%	5905-691-0195
R17	Comp., 10 kΩ ±5%	6099-3105	75042	BTS, 10 kΩ ±5%	5905-683-2238
R18	Comp., 100 Ω ±5%	6099-1105	75042	BTS, 100 kΩ ±5%	
R19	Comp., 5.6 kΩ ±5%	6099-2565	75042	BTS, 5.6 kΩ ±5%	5905-691-0195
	TRANSISTORS				
Q1 thru Q3	Type 2N3414	8210-1047	24446	2N3414	5961-989-2749

NOTES

CONNECTIONS FOR VARIOUS TYPES OF OPERATION

1 DC COUPLED "START" SIGNAL (PIN 49)

A SIGNAL MUST BE PRESENT FOR 20 μs OR LONGER. MAXIMUM OF -50 V.

B FOR START TO OCCUR ON POSITIVE GOING TRANSITION, CONNECT ANCHOR TERMINAL (AT) 2 to AT1

FOR TRIGGER LEVEL OF

+5 V CONNECT AT3 TO AT4
+15 V CONNECT AT3 TO AT5
-5 V CONNECT AT3 TO AT6

C FOR START TO OCCUR ON NEGATIVE GOING TRANSITION, CONNECT AT3 TO AT1

FOR TRIGGER LEVELS OF

+5 V CONNECT AT2 TO AT
+15 V CONNECT AT2 TO AT
-5 V CONNECT AT2 TO AT6

2 AC COUPLED START SIGNAL (PIN 49)

A SIGNAL MUST BE GREATER THAN 8 V PEAK AND PRESENT FOR 20 μs OR LONGER

B FOR START TO OCCUR ON POSITIVE GOING TRANSITION, CONNECT AT3 TO AT4 AND AT2 TO AT1

C FOR START TO OCCUR ON NEGATIVE GOING TRANSITION, CONNECT AT2 TO AT6 AND AT3 TO AT1

3 INHIBIT SIGNAL (PIN 23)

THE INHIBIT SIGNAL INPUT IS COMPATIBLE WITH THE TYPE OF BOARD OBTAINED: HIGH LEVEL OR LOW LEVEL DATA. FOR HIGH-LEVEL DATA, R13 IS SUPPLIED WITH THE BOARD. FOR LOW LEVEL DATA R13 IS REMOVED AND R12, THE SAME VALUE RESISTOR, IS SUPPLIED WITH THE BOARD. THE LEVELS FOR THE INHIBIT SIGNAL CAN BE CHANGED BY INTERCHANGING R12 AND R13.

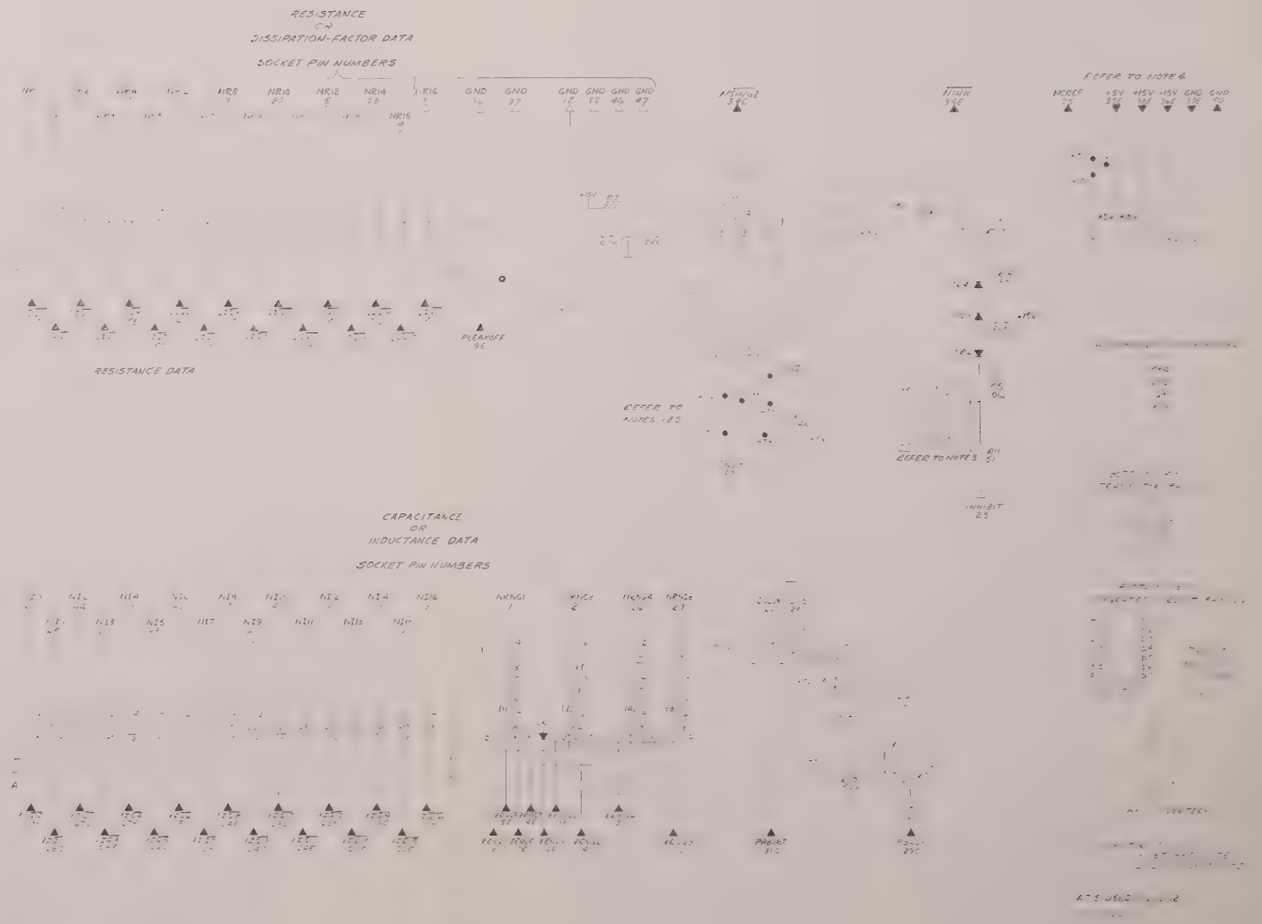
FOR OPERATION WITH THE GR TYPE 1137 DATA PRINTER, USE R13 (REMOVE R12).
FOR STANDARD T^2L LEVEL, USE R12 (REMOVE R13).

4 INTERCHANGING LOGIC LEVELS

IC'S ENCLOSED BY DASHED LINES ARE IN SOCKETS AND CAN BE INTERCHANGED FOR DIFFERENT LOGIC LEVELS (STANDARD T^2L 0.5 V OR 2.15 V).

FOR 5 V LEVEL, CONNECT AT10 TO AT11
FOR +15 V LEVEL, CONNECT AT10 TO AT12

THE APPLICABLE CONNECTION IS MADE ON THE BOARD SUPPLIED TO THE USER AND CAN BE CONNECTED TO THE OTHER ANCHOR TERMINAL IF IT IS DESIRED TO CHANGE LEVELS.



RESISTANCE IS IN OHMS, K=10^3, M=10^6
CAPACITANCE IS IN FARADS, μ=10^{-6}, p=10^{-12}
VOLTAGES EXPLAINED IN INSTRUCTION BOOK SERVICE NOTES
(F) PANEL CONTROL, (R) REAR CONTROL
(S) SCREWDRIVER CONTROL, WIRE TIE TP-TEST POINT
COMPLETE REFERENCE DESIGNATION INCLUDES SUBASSEMBLY LETTER: C IN B IN ETC

SWITCH NUMBERING
6 0 4 F
FRONT, REAR
CONTACTS: FIRST CONTACT CW FROM STRUT SCREW ABOVE KEY, 3 CH SECTION, SECTION NEAREST PANEL IS 1
MOTORS SHOWN CCW

CONNECTIONS
OUTPUT - LEAVES SUBASSEMBLY
INPUT FROM DIFFERENT SUBASSEMBLY
OUTPUT REMAINS ON SUBASSEMBLY
INPUT FROM SAME SUBASSEMBLY

Figure 6-17. Data Output board schematic, N.

PROGRAM BOARD (P/N 1683-4770) ELECTRICAL REPLACEABLE PARTS

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
CAPACITORS					
C1	Tantalum, 22 µF ±20%	4450-5300	56289	150D226X0015B2	5910-752-4270
C2	Ceramic, 2.2 µF ±20%	4400-2080	80183	5C13, 2.2 µF ±20%	
C3	Tantalum, 22 µF ±20%	4450-5300	56289	150D226X0015B2	5910-752-4270
C4	Ceramic, 180 pF ±10%	4404-1188	72982	831, 180 pF ±10%	5910-075-9607
C5	Ceramic, 10000 pF +80-20%	4406-3109	72982	811, .01 µF +80-20%	5910-977-5779
C6	Ceramic, .1 µF ±20%	4400-2050	80183	5C13, .1 µF ±20%	5910-080-4646
C7	Ceramic, 1000 pF +80-20%	4404-2109	72982	831, .001 µF +80-20%	5910-075-9607
C8	Ceramic, .02 µF +80-20%	4402-3200	01121	35-203W	5910-974-5698
C9	Ceramic, 1.0 µF ±20%	4400-2070	80183	5C13, 1 µF ±20%	5910-083-6445
C10	Ceramic, .02 µF +80-20%	4402-3200	01121	35-203W	5910-974-5698
C11	Ceramic, 2.2 µF ±20%	4400-2080	80183	5C13, 2.2 µF ±20%	
C12	Ceramic, 10,000 pF +80-20%	4406-3109	72982	811, .01 µF +80-20%	5910-977-5779
C13 and C14	Ceramic, 10,000 pF +80-20%	4406-3109	72982	811, .01 µF +80-20%	5910-977-5779
C15	Tantalum, 6.8 pF ±20%	4450-5000	56289	150D685X0035B2	5910-814-5869
C16	Ceramic, 2.2 µF ±20%	4400-2080	80183	5C13, 2.2 µF ±20%	
C17	Ceramic, 47 µF ±20%	4400-2054	80183	5C13, .47 µF ±20%	5910-933-4005
C18	Ceramic, .02 µF +80-20%	4402-3200	01121	35-203W	5910-974-5698
C19	Ceramic, 1.0 µF ±20%	4400-2070	80183	5C13, 1 µF ±20%	5910-083-6445
C20	Ceramic, 2.2 µF ±20%	4400-2080	80183	5C13, 2.2 µF ±20%	
C21 thru C23	Ceramic, 1.0 µF ±20%	4400-2070	80183	5C13, 1 µF ±20%	5910-083-6445
DIODES					
CR1 thru CR6	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR7	Type 1N750	6083-1003	07910	1N750	
CR8 thru CR16	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR17 thru CR25	Type 1N995	6082-1002	80368	1N995	5961-893-6762
INDICATOR LAMPS					
DS1 thru DS10	Lamp	5600-1071	17460	2309	
INTEGRATED CIRCUITS					
IC1 thru IC8	Digital	5431-9452	96214	SN15845N	
IC9 and IC10	Digital	5431-9462	96214	SN15846N	
IC11	Digital	5431-9442	96214	SN15844N	
IC12	Digital	5431-9362	96214	SN15836N	
IC13	Digital	5431-9442	96214	SN15844N	
IC14 and IC15	Digital	5431-9462	96214	SN15846N	
IC16	Digital	5431-9442	96214	SN15844N	
IC17	Digital	5431-9462	96214	SN15846N	
IC18 and IC19	Digital	5431-9442	96214	SN15844N	
IC20 and IC21	Digital	5431-9322	96214	SN15832N	
IC22	Digital	5431-9372	96214	SN15837N	
IC23 thru IC26	Digital	5431-9462	96214	SN15846N	
IC27	Digital	5431-9302	96214	SN15830N	
IC28	Digital	5431-9099	96214	SN158099N	
IC29	Digital	5431-9462	96214	SN15846N	
IC30	Digital	5431-9362	96214	SN15836N	
RESISTORS					
R3	Comp, 560 Ω ±5%	6099-1565	75042	BTS, 560 Ω ±5%	
R4	Comp, 1.5 kΩ ±5%	6099-2155	75042	BTS, 1.5 kΩ ±5%	
R5	Comp, 7.5 kΩ ±5%	6099-2755	75042	BTS, 7.5 kΩ ±5%	
R6	Comp, 560 Ω ±5%	6099-1565	75042	BTS, 560 Ω ±5%	
R7	Comp, 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R8	Comp, 75 Ω ±5%	6099-0755	75042	BTS, 75 Ω ±5%	
R9	Comp, 15 kΩ ±5%	6099-3155	75042	BTS, 15 kΩ ±5%	5905-681-8818
R10	Comp, 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R11	Comp., 75 kΩ ±5%, 1/4 W	6099-2755	75042	BTS, 7.5 kΩ, ±5%	
R12	Comp, 10 kΩ ±5%	6099-3105	75042	BTS, 10 kΩ ±5%	5905-683-2238
R13	Comp, 10 Ω ±5%	6099-0105	75042	BTS, 10 Ω ±5%	5905-809-8596

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
R14	Comp, 20 kΩ ±5%	6099-3205	75042	Comp., 20 kΩ ±5%	
R15	Comp, 5.1 kΩ ±5%	6099-2515	75042	BTS, 5.1 kΩ ±5%	5905-683-2241
R16	Comp, 3 kΩ ±5%	6099-2305	75042	BTS, 3 kΩ ±5%	5905-682-4097
R17	Comp, 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R18	Comp, 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R19	Comp, 5.1 kΩ ±5%	6099-2515	75042	BTS, 5.1 kΩ ±5%	5905-683-2241
R20	Comp, 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R21	Comp, 560 Ω ±5%	6099-1565	75042	BTS, 560 Ω ±5%	
R22	Comp, 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R23	Comp, 3.9 kΩ ±5%	6099-2395	75042	BTS, 3.9 kΩ ±5%	
R24	Comp, 16 kΩ ±5%	6099-3165	75042	BTS, 16 kΩ ±5%	
R25	Comp., 240 Ω ±5%, 1/4 W	6099-1245	75042	BTS, 240 kΩ, ±5%	
R26	Comp, 270 kΩ ±5%	6099-4275	75042	BTS, 270 kΩ ±5%	
R27	Comp, 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R28	Comp, 5.6 kΩ ±5%	6099-2565	75042	BTS, 5.6 kΩ ±5%	5905-691-0195
R29	Comp, 51 kΩ ±5%	6099-3515	75042	BTS, 51 kΩ ±5%	5905-682-4103
R30	Comp, 5.6 kΩ ±5%	6099-2565	75042	BTS, 5.6 kΩ ±5%	5905-691-0195
R31	Comp, 3.9 kΩ ±5%	6099-2395	75042	BTS, 3.9 kΩ ±5%	
R32	Comp, 16 kΩ ±5%	6099-3165	75042	BTS, 16 kΩ ±5%	
R33	Comp, 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R34	Comp, 2 kΩ ±5%	6099-2205	75042	BTS, 2 kΩ ±5%	5905-686-3370
R35	Comp, 12 kΩ ±5%	6099-3125	75042	BTS, 12 kΩ ±5%	
R36	Comp, 9.1 kΩ ±5%	6099-2915	75042	BTS, 9.1 kΩ ±5%	5905-279-4619
R37	Comp, 6.2 kΩ ±5%	6099-2625	75042	BTS, 6.2 kΩ ±5%	5905-682-4100
R38	Comp, 7.5 kΩ ±5%	6099-2755	75042	BTS, 7.5 kΩ ±5%	
R39	Comp., 51 kΩ ±5%, 1/4 W	6099-3515	75042	BTS, 51 kΩ, ±5%	5905-682-4103
R40 thru R46	Comp, 5.6 kΩ ±5%	6099-2565	75042	BTS, 5.6 kΩ ±5%	5905-691-0195
R47	Comp, 3 kΩ ±5%	6099-2305	75042	BTS, 3 kΩ ±5%	5905-682-4097
R48	Comp, 100 Ω ±5%	6099-1105	75042	BTS, 100 Ω ±5%	
R49	Comp, 30 Ω ±5%	6099-0305	75042	BTS, 30 Ω ±5%	
R50	Comp., 3.9 kΩ ±5%, 1/4 W	6099-2395	75042	BTS, 3.9 kΩ, ±5%	
R51	Comp, 16 kΩ ±5%	6099-3165	75042	BTS, 16 kΩ ±5%	
R52	Comp, 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R55 and R56	Comp, 3 kΩ ±5%	6099-2305	75042	BTS, 3 kΩ ±5%	5905-682-4097
R57 and R58	Comp, 6.8 k ±5%	6099-2685	75042	BTS, 6.8 kΩ ±5%	5905-686-9997
R59	Comp, 20 Ω ±5%	6100-0205	01121	RC20GF200J	5905-279-3520
TRANSISTORS					
Q1	Type 2N3646	8210-1119	07263	2N3646	5961-964-5753
Q2	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749
Q3	Type 2N4125	8210-1125	04713	2N4125	
Q4 and Q5	Type 2N3391A	8210-1092	24454	2N3391A	
Q6	Type 2N4125	8210-1125	04713	2N4125	
Q7	Type 2N3646	8210-1119	07263	2N3646	5961-964-5753
Q8	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749
Q9	Type 2N3646	8210-1119	07263	2N3646	5961-964-5753
Q10 thru Q14	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749
Q15	Type 2N4125	8210-1125	04713	2N4125	
Q16 and Q17	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749
Q18 and Q19	Type 2N4125	8210-1125	04713	2N4125	
Q20 and Q21	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749

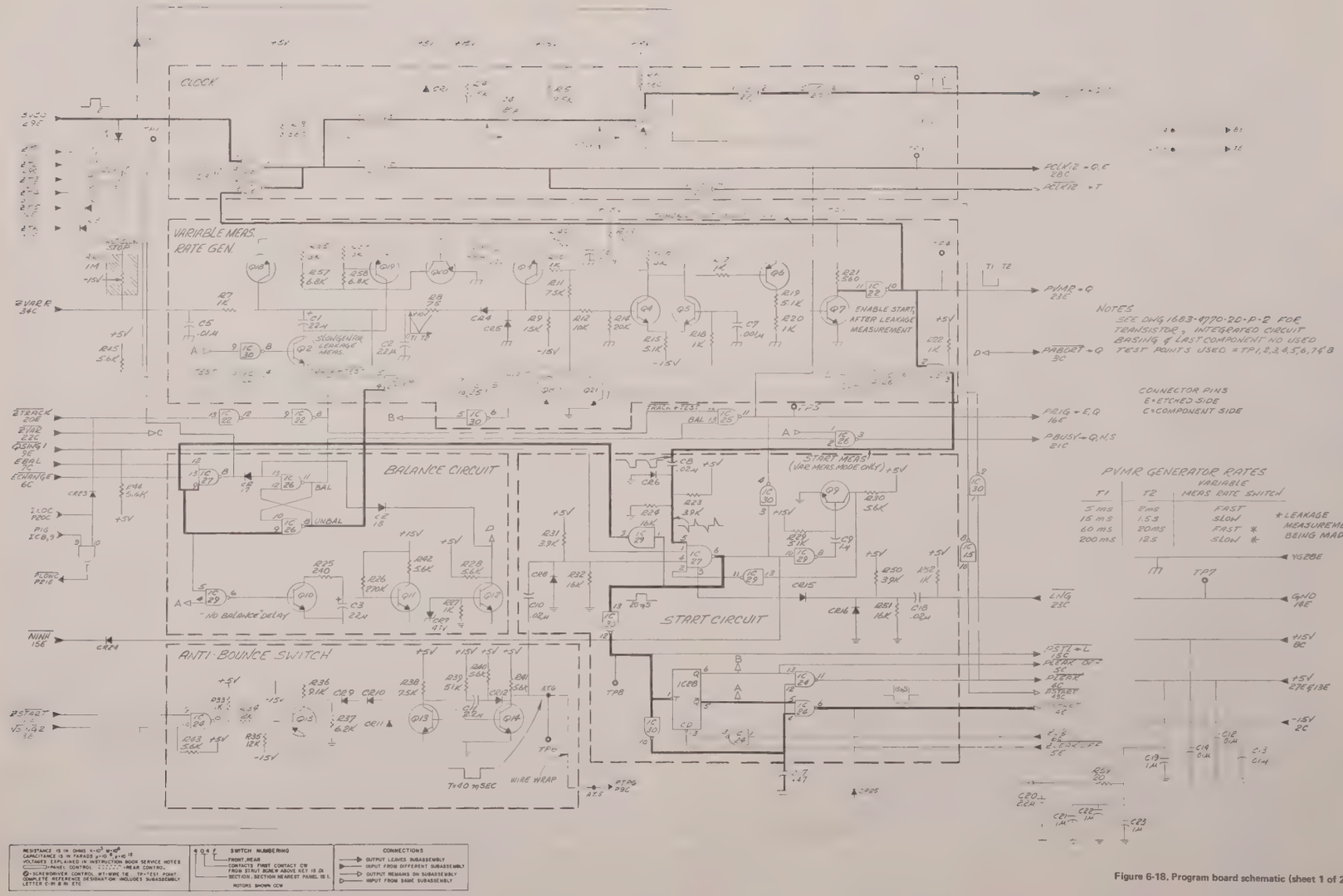

CLOCK
VARIABLE MEAS. RATE GEN.
BALANCE CIRCUIT
START CIRCUIT
ANTI-BOUNCE SWITCH
START MEAS. (VAR MEAS MODE ONLY)
SLOW/CENTOR LEAKAGE MEAS.
ENABLE START, AFTER LEAKAGE MEASUREMENT
"NO BALANCE" DELAY
WIRE WRAP
NOTES
SEE DWG 1683-0770-20-P-2 FOR TRANSISTOR, INTEGRATED CIRCUIT BASING & LAST COMPONENT NO USED
TEST POINTS USED = TP1,2,3,4,5,6,7&8
CONNECTOR PINS
E=ETCHED SIDE
C=COMPONENT SIDE
PVMR GENERATOR RATES
VARIABLE MEAS RATE SWITCH
T1 | T2 | FAST/SLOW
5 ms | 8ms | FAST
15 ms | 1.5s | SLOW
60 ms | 20ms | FAST *
200 ms | 12s | SLOW *
* LEAKAGE MEASUREMENT BEING MADE
RESISTANCE IS IN OHMS K=10³ M=10⁶
CAPACITANCE IS IN FARADS μ=10⁻⁶ p=10⁻¹²
VOLTAGES EXPLAINED IN INSTRUCTION BOOK SERVICE NOTES
SWITCH NUMBERING
CONNECTIONS
OUTPUT LEAVES SUBASSEMBLY
INPUT FROM DIFFERENT SUBASSEMBLY
OUTPUT REMAINS ON SUBASSEMBLY
INPUT FROM SAME SUBASSEMBLY
MOTORS SHOWN CCW

Figure 6-18. Program board schematic (sheet 1 of 2), P.

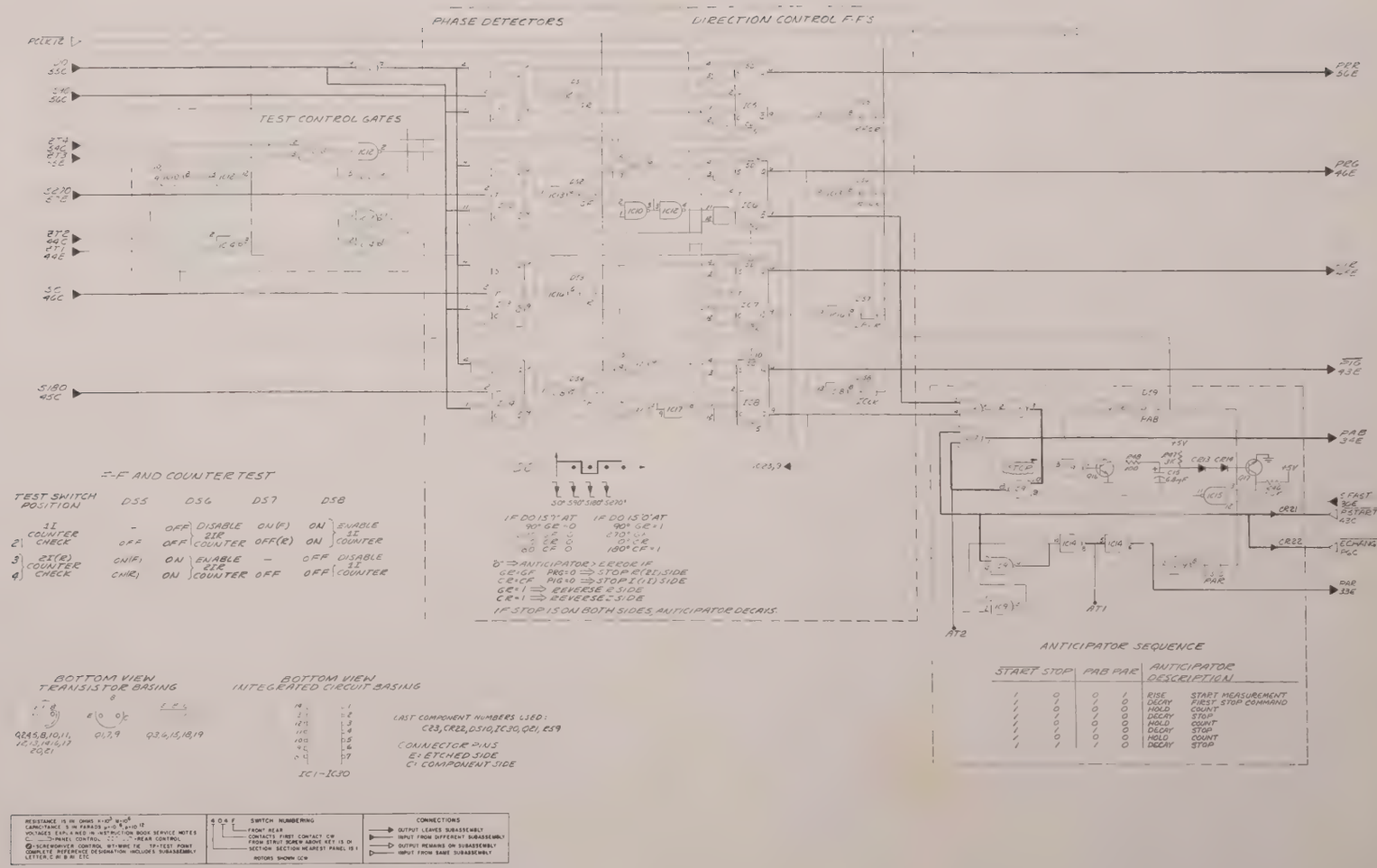


Figure 6-19. Program board schematic (sheet 2 of 2), P.

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
	AUXILIARY BOARD (P/N 1683-4709) ELECTRICAL REPLACEABLE PARTS				
CAPACITORS					
C1 and C2	Ceramic, 0.1 µF +80-20%	4403-4100	80131	CC63, 0.1 µF +80-20%	5910-974-5699
C3 thru C29	Ceramic, .01 µF +80-20%	4401-3100	80131	CC61, .01 µF +80-20%	5910-974-5697
C30	Ceramic, 0.1 µF +80-20%	4403-4100	80131	CC63, 0.1 µF +80-20%	5910-974-5699
C31	Ceramic, .01 µF +80-20%	4401-3100	80131	CC61, .01 µF +80-20%	5910-974-5697
INTEGRATED CIRCUITS					
IC1	Linear	5431-9462	07263	DTµL-946	
IC2	Linear	5431-9362	07263	DTµL-936	
IC3	Linear	5431-9462	07263	DTµL-946	
IC4	Linear	5431-9362	07263	DTµL-936	
IC5	Linear	5431-9462	07263	DTµL-946	
IC6	Linear	5431-9362	07263	DTµL-936	
IC7	Linear	5431-9462	07263	DTµL-946	
IC8	Linear	5431-9362	07263	DTµL-936	
IC9	Linear	5431-9462	07263	DTµL-946	
IC10	Linear	5431-9362	07263	DTµL-936	
IC11	Linear	5431-9462	07263	DTµL-946	
IC12	Linear	5431-9362	07263	DTµL-936	
IC13	Linear	5431-9362	07263	DTµL-936	
IC14	Linear	5431-9452	07263	DTµL-945	
RESISTORS					
R1 thru R26	Comp., 51 Ω ±5%	6099-2565	75042	BTS, 5.6 kΩ ±5%	5905-691-0195
R27	Comp.,330 Ω ±5%	6099-1335	75042	BTS, 330 Ω ±5%	5905-686-3369
R28	Comp.,5.6 kΩ ±5%	6099-2565	75042	BTS, 5.6 kΩ ±5%	5905-691-0195
R29	Comp., 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R30	Comp.,150 Ω ±5%	6099-1155	75042	BTS, 150 Ω ±5%	5905-683-2243
R31 thru R53	Comp., 51 Ω ±5%	6099-0515	75042	BTS, 51 Ω ±5%	
R55 thru R58	Comp., 51 Ω ±5%	6099-0515	75042	BTS, 51 Ω ±5%	
R59	Comp., 5.6 kΩ ±5%	6099-2565	75042	BTS, 5.6 kΩ ±5%	5905-691-0195
R60	Comp., 470 Ω ±5%	6099-1475	75042	BTS, 470 Ω ±5%	5905-683-2242
R61	Comp., 51 Ω ±5%	6099-0515	75042	BTS, 51 Ω ±5%	

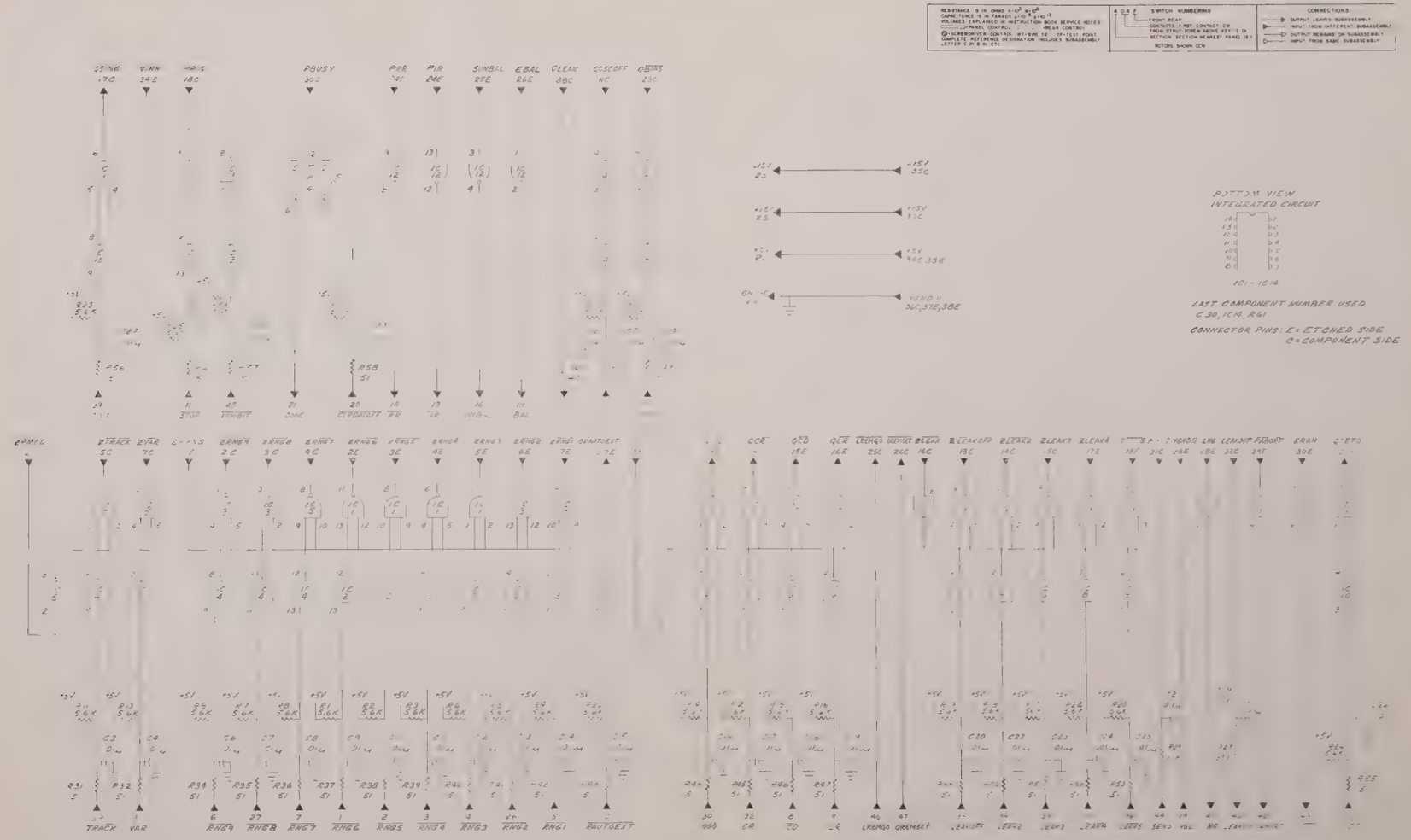


Figure 6-20. Auxiliary (Data Input) board schematic, Q.

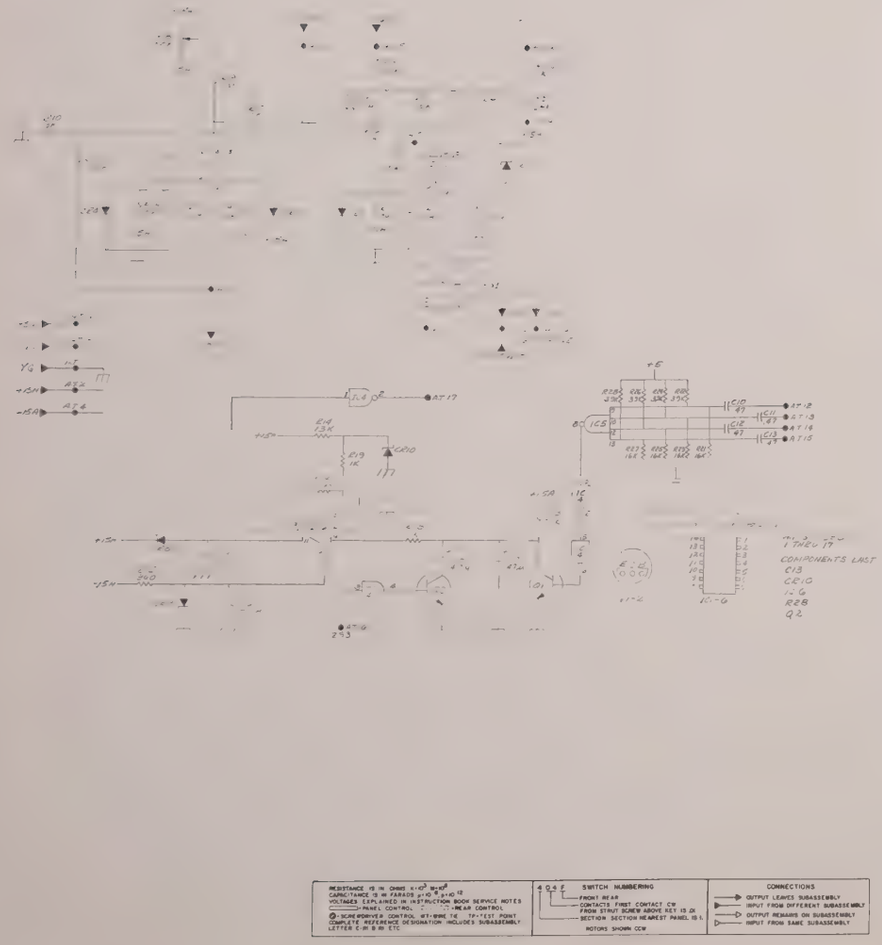


Figure 6-21. Auxiliary comparator board schematic, R.

AUXILIARY COMPARATOR BOARD (P/N 1683-4773) ELECTRICAL REPLACEABLE PARTS

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
CAPACITORS					
C1 thru C6	Ceramic, 0.1 µF, ±20%, 50 V	4400-2050	80183	5C13, 0.1 µF, ±20%	5910-080-4646
C7	Tantalum, 0.47 µF, ±20%, 75 V	4450-4310	56289	150D474X0075A2	
C8	Tantalum, 4.7 µF, ±20%, 50 V	4450-4990	56289	150D475X0050B2	
C9	Ceramic, 0.1 µF, ±20%, 50 V	4400-2050	80183	5C13, 0.1 µF, ±20%	5910-080-4646
C10 thru C13	Ceramic, 0.47 µF, ±20%, 50 V	4400-2054	80183	5C13, 0.47 µF, ±20%	5910-933-4005
DIODES					
CR2	Type 1N753A	6083-1006	07910	1N753A	5961-752-6121
CR3	Type 1N748A	6083-1002	07910	1N748A	5960-800-3973
CR4	Type 1N753A	6083-1006	07910	1N753A	5961-752-6121
CR5 and CR6	Type 1N995	6082-1002	80368	1N995	5961-893-6762
CR7 and CR8	Type 1N748A	6083-1002	07910	1N748A	5960-800-3973
CR9 and CR10	Type 1N753A	6083-1006	1N753A		5961-752-6121
INTEGRATED CIRCUITS					
IC1	Digital	5431-9452	96214	SN15845N	
IC2	Linear	5432-7102	07263	U6E7710393	
IC3	Type U5B771039X (Linear)	5432-7102	07263	U5B771039X	
IC4	Type DTUL-936 (Digital)	5431-9362	07263	DTUL-936	
IC5	Type DTUL-932 (Digital)	5431-9322	07263	DTUL-932	
IC6	Type U6E7710393 (Linear)	5432-7102	07263	U6E7710393	
JACKS					
	Signal Jack	4260-0850	22526	47330	
RESISTORS					
R1	Comp., 360 Ω ±5%	6099-1365	75042	BTS, 360 Ω ±5%	
R2 and R3	Comp., 75 kΩ ±5%	6099-3755	75042	BTS, 75 kΩ ±5%	
R4	Comp., 1MΩ ±5%	6099-5105	75042	BTS, 1MΩ ±5%	
R5	Comp., 24 kΩ, ±5%, 1/4 W	6099-3245	75042	BTS, 24 kΩ, ±5%	
R6 and R7	Comp., 3 kΩ ±5%	6099-2305	75042	BTS, 3 kΩ ±5%	5905-682-4097
R8	Pot., cerment, rect., 50 kΩ ±10%	6049-0191	80194	3009P, 50 kΩ ±10%	
R9	Comp., 1MΩ ±5%	6099-5105	75042	BTS, 1MΩ ±5%	
R10	Comp., 3 kΩ ±5%	6099-2305	75042	BTS, 75 kΩ ±5%	5905-682-4097
R11	Comp., 120 kΩ ±5%	6099-4125	75042	BTS, 120 kΩ ±5%	5905-686-9993
R12	Comp., 360 Ω ±5%	6099-1365	75042	BTS, 360 Ω ±5%	
R13	Comp., 51 kΩ, ±5%, 1/4 W	6099-3515	75042	BTS, 51 kΩ, ±5%	5905-682-4103
R14	Comp., 13 kΩ, ±5%, 1/4 W	6099-3135	75042	BTS, 13 kΩ, ±5%	5905-702-4439
R15	Comp., 360 Ω, ±5%, 1/4 W	6099-1365	75042	BTS, 360 Ω, ±5%	
R16	Comp., 1.6 kΩ, ±5%, 1/4 W	6099-2165	75042	BTS, 1.6 kΩ, ±5%	
R18 thru R20	Comp., 1 kΩ, ±5%, 1/4 W	6099-2105	75042	BTS, 1 kΩ, ±5%	5905-681-6422
R21	Comp., 16 kΩ, ±5%, 1/4 W	6099-3165	75042	BTS, 16 kΩ, ±5%	
R22	Comp., 3.9 kΩ, ±5%, 1/4 W	6099-2395	75042	BTS, 3.9 kΩ, ±5%	
R23	Comp., 16 kΩ, ±5%, 1/4 W	6099-3165	75042	BTS, 16 kΩ, ±5%	
R24	Comp., 3.9 kΩ, ±5%, 1/4 W	6099-2395	75042	BTS, 3.9 kΩ, ±5%	
R25	Comp., 16 kΩ, ±5%, 1/4 W	6099-3165	75042	BTS, 16 kΩ, ±5%	
R26	Comp., 3.9 kΩ, ±5%, 1/4 W	6099-2395	75042	BTS, 3.9 kΩ, ±5%	
R27	Comp., 16 kΩ, ±5%, 1/4 W	6099-3165	75042	BTS, 16 kΩ, ±5%	
R28	Comp., 3.9 kΩ, ±5%, 1/4 W	6099-2395	75042	BTS, 3.9 kΩ, ±5%	
TRANSISTORS					
Q1 and Q2	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749

REFERENCE BOARD (P/N 1683-4780) ELECTRICAL REPLACEABLE PARTS

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
CAPACITORS					
C1	Tantalum, 15 µF, ±20%, 20 V	4450-5200	56289	150D156X0020B2	5910-855-6335
C2	Ceramic, 39 pF ±10%	4404-0398	72982	831, 39 pF ±10%	
C3	Plastic, .0682 µF ±1%	4860-7867	84411	663UW, .0682 µF 1%	5910-902-5189
C4	Plastic, .00930 µF ±2%	4860-7590	84411	663UW, .00930 µF ±2%	5910-902-5663
C5	Plastic, .0682 µF ±1%	4860-7867	84411	663UW, .0682 µF 1%	5910-902-5189
C6	Plastic, .00930 µF ±2%	4860-7590	84411	663UW, .00930 µF ±2%	5910-902-5663
C7	Tantalum, 180 µF ±20%	4450-5617	56289	150D187X0006R2	
C8	Ceramic, .01 µF +80-20%	4401-3100	80131	CC61, .01 µF +80-20%	5910-974-5697
C9	Ceramic, .01 µF, +80-20%, 100 V	4401-3100	80131	CC61, .01 µF, +80-20%	5910-974-5697
C10	Tantalum, 180 µF ±20%	4450-5617	56289	150D187X0006R2	
C11	Ceramic, .01 µF +80-20%	4401-3100	80131	CC61, .01 µF +80-20%	5910-974-5697
C12	Ceramic, .01 µF, +80-20%, 100 V	4401-3100	80131	CC61, .01 µF, +80-20%	5910-974-5697
C13	Ceramic, 2.2 µF ±20%	4400-2080	80183	5C13, 2.2 µF ±20%	
C14	Tantalum, 1.0 µF ±20%	4450-4300	56289	150D105X0035A2	5910-726-5003
C15	Tantalum, 6.8 µF ±20%	4450-5000	56289	150D685X0035B2	5910-814-5869
C16	Ceramic, 2.2 µF ±20%	4400-2080	80183	5C13, 2.2 µF ±20%	
C17	Tantalum, 1.0 µF ±20%	4450-4300	56289	150D105X0035B2	5910-726-5003
C18	Tantalum, 6.8 µF ±20%	4450-5000	56289	150D685X0035B2	5910-814-5869
C19	Ceramic, 39 pF ±10%	4404-0398	72982	831, 39 pF ±10%	
C20	Ceramic, 39 pF ±10%	4404-0398	72982	831, 39 pF ±10%	
C23	Ceramic, 39 pF ±10%	4404-0398	72982	831, 39 pF ±10%	
C24	Ceramic, 1 µF ±20%	4400-2070	80183	5C13, 1 µF ±20%	5910-083-6445
C25	Mylar, 0.1 µF, ±10%, 100 V	4860-8250	84411	663 UW, .1 µF, ±10%	
C26	Plastic, .009 µF ±5%	4860-7510	84411	663UW, .009 µF ±5%	
C27	Mica, 768 pF ±1%	4710-0768	14655	22A, 768 pF ±1%	
C29	Ceramic, 1 µF ±20%	4400-2070	80183	5C13, 1 µF ±20%	5910-083-6445
C30	Ceramic, .01 µF +80-20%	4401-3100	80131	CC61, .01 µF +80-20%	5910-974-5697
C31	Ceramic, 2.2 µF ±20%	4400-2080	80183	5C13, 2.2 µF ±20%	
C33	Ceramic, 1 µF ±20%	4400-2070	80183	5C13, 1 µF ±20%	5910-083-6445
C34	Ceramic, 1 µF ±20%	4400-2070	80183	5C13, 1 µF ±20%	5910-083-6445
C35	Ceramic, 2.2 µF ±20%	4400-2080	80183	5C13, 2.2 µF ±20%	
C37	Ceramic, 39 pF ±10%	4404-0398	72982	831, 39 pF ±10%	
C38	Ceramic, 1 µF ±20%	4400-2070	80183	5C13, 1 µF ±20%	5910-083-6445
C39	Ceramic, 1 µF ±20%	4400-2070	80183	5C13, 1 µF ±20%	5910-083-6445
C42	Ceramic, 39 pF ±10%	4404-0398	72982	831, 39 pF ±10%	
C43	Tantalum, 47 µF ±20%	4450-5614	56289	150D476X0020R2	
C46 thru C49	Ceramic, 1.0 µF ±20%	4400-2070	80183	5C13, 1.0 µF ±20%	5910-083-6445
C50	Ceramic, 1000 pF ±20%	4404-2100	72982	831, 1000 pF ±20%	
C51 and C52	Ceramic, 1.0 µF ±20%	4400-2070	80183	5C13, 1.0 µF ±20%	5910-083-6445
C53	Ceramic, 1 µF ±20%	4400-2070	80183	5C13, 1 µF ±20%	5910-083-6445
C54	Ceramic, .1 µF ±20%	4400-2050	80183	5C13, .1 µF ±20%	5910-080-4646
C55	Ceramic .01 µF +80-20%	4401-3100	80131	CC61, .01 µF +80-20%	5910-974-5697
DIODES					
CR1	Type 1N748A	6083-1002	07910	1N748A	5960-800-3973
CR2	Type 1N753A	6083-1006	07910	1N753A	5961-752-6121
CR3	Type 1N748A	6083-1002	07910	1N748A	5960-800-3973
CR4	Type 1N753A	6083-1006	07910	1N753A	5961-752-6121
CR5 thru CR8	Type 1N645	6082-1016	24446	1N645	5961-087-6047
CR9 thru CR16	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR18	Type 1N750	6083-1003	07910		
CR19 thru CR25	Type 1N995	6082-1002	80368	1N995	5961-893-6762
INTEGRATED CIRCUITS					
IC1 and IC2	Linear	5432-1004	12040	LM301A	
IC3 and IC4	Linear	5432-7101	07263	U5B771039X	
IC5 thru IC12	Linear	5432-1004	12040	LM301A	
IC14 thru IC18	Digital	5431-9362	96214	SN15836N	
RESISTORS					
R1	Comp, 1.1 kΩ ±5%	6099-2115	75042	BTS, 1.1 kΩ ±5%	
R2	Comp., 82 kΩ ±5%, 1/4 W	6099-3825	75042	BTS, 82 kΩ, ±5%	
R3 and R4	Film, 18.2 kΩ ±1%	6250-2182	75042	CEA, 18.2 kΩ ±1%	5905-686-3373
R5	Comp, 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422

List continued

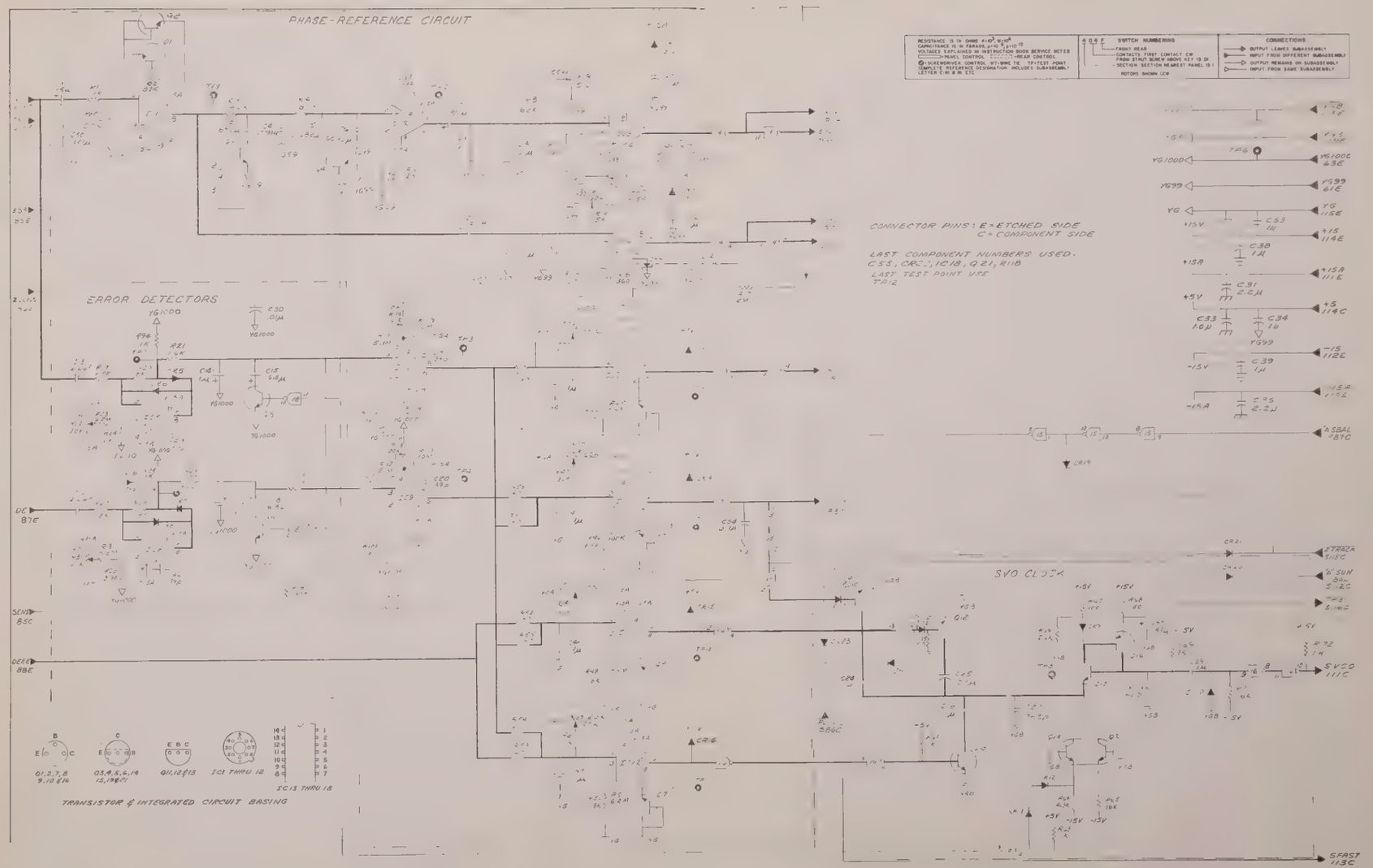


Figure 6-22. Reference board schematic, S.

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
R6	Comp., 2 kΩ ±5%	6099-2205	75042	BTS, 2 kΩ ±5%	5905-686-3370
R7	Comp., 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R8	Comp., 62 kΩ ±5%	6099-3625	75042	BTS, 2.0 MΩ ±5%	
R9	Pot.,wire wound, 5 kΩ ±10%	6051-2509	80294	3007P-1-502	
R10	Comp, 100 Ω ±5%	6099-1105	75042	BTS, 100 Ω ±5%	
R11	Comp, 20 MΩ ±5%	6099-5205	75042	BTS, 2.0 MΩ ±5%	
R12	Comp, 360 Ω ±5%	6099-1365	75042	BTS, 360 Ω ±5%	
R13	Pot.,wire wound, 5 kΩ ±10%	6051-2509	80294	3007P-1-502	
R14	Comp, 62 kΩ ±5%	6099-3625	75042	BTS, 62 kΩ ±5%	
R15	Comp, 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R16	Comp, 100 Ω ±5%	6099-1105	75042	BTS, 100 Ω ±5%	
R17	Comp, 20 MΩ ±5%	6099-5205	75042	BTS, 2.0 MΩ ±5%	
R18	Comp, 360 Ω ±5%	6099-1365	75042	BTS, 360 Ω ±5%	
R19	Comp, 1.5 kΩ ±5%	6099-2155	75042	BTS, 1.5 kΩ ±5%	
R20	Comp, 18 kΩ ±5%	6099-3185	75042	BTS, 18 kΩ ±5%	5905-687-0000
R21	Comp, 1.6 kΩ ±5%	6099-2165	75042	BTS, 1.6 kΩ ±5%	
R22	Pot.,wire wound, 20 kΩ ±10%	6051-3209	02660	2600PC, 20 kΩ ±10%	
R23	Comp, 6.2 MΩ ±5%	6099-5625	75042	BTS, 7.5 MΩ ±5%	
R24	Comp, 2 kΩ ±5%	6099-2205	75042	BTS, 2 kΩ ±5%	5905-686-3370
R25	Comp, 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R27	Comp, 1.5 kΩ ±5%	6099-2155	75042	BTS, 1.5 kΩ ±5%	
R28	Comp, 18 kΩ ±5%	6099-3185	75042	BTS, 18 kΩ ±5%	5905-687-0000
R29	Comp, 1.6 kΩ ±5%	6099-2165	75042	BTS, 1.6 kΩ ±5%	
R30	Pot.,wire wound, 20 kΩ ±10%	6051-3209	02660	2600PC, 20 kΩ ±10%	
R31	Comp, 6.2 MΩ ±5%	6099-5625	75042	BTS, 6.2 MΩ ±5%	
R33	Comp, 3.9 kΩ ±5%	6099-2395	75042	BTS, 3.9 kΩ ±5%	
R34	Comp, 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R36 thru R39	Pot.,wire wound, 20 kΩ ±10%	6051-3209	02660	2600PC, 20 kΩ ±10%	
R40 thru R43	Comp, 130 kΩ ±5%	6099-4135	75042	BTS, 130 kΩ ±5%	
R44	Comp, 2 kΩ ±5%	6099-2205	75042	BTS, 2 kΩ ±5%	5905-686-3370
R45	Comp, 8.2 MΩ ±5%	6099-5825	75042	BTS, 8.2 MΩ ±5%	
R46	Comp, 1.5 kΩ ±5%	6099-2155	75042	BTS, 1.5 kΩ ±5%	
R47	Comp, 100 kΩ ±5%	6099-4105	75042	BTS, 100 kΩ ±5%	5905-686-3129
R48	Comp, 1.8 kΩ ±5%	6099-2185	75042	BTS, 1.8 kΩ ±5%	5905-688-3738
R49	Comp, 7.5 MΩ ±5%	6099-5755	75042	BTS, 7.5 MΩ ±5%	
R50	Comp, 1.3 kΩ ±5%	6099-2135	75042	BTS, 1.3 kΩ ±5%	5905-686-3119
R51	Comp, 6.2 MΩ ±5%	6099-5625	75042	BTS, 6.2 MΩ ±5%	
R52 and R53	Comp, 1 kΩ ±5%	6099-2205	75042	BTS, 2 kΩ ±5%	5905-686-3370
R54	Comp, 2 kΩ ±5%	6099-2205	75042	BTS, 2 kΩ ±5%	5905-686-3370
R55	Comp, 10 kΩ ±5%	6099-3105	75042	BTS, 10 kΩ ±5%	5905-683-2238
R56	Comp, 2 kΩ ±5%	6099-2205	75042	BTS, 2 kΩ ±5%	5905-686-3370
R57	Comp., 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R58	Comp, 16 kΩ ±5%	6099-3165	75042	BTS, 16 kΩ ±5%	
R59	Comp, 2 kΩ ±5%	6099-2205	75042	BTS, 2 kΩ ±5%	5905-686-3370
R60	Comp., 1 kΩ, ±5%, 1/4 W	6099-2105	75042	BTS, 1 kΩ, ±5%	5905-681-6422
R61 thru R63	Comp, 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R64	Comp, 4.3 kΩ ±5%	6099-2435	75042	BTS, 4.3 kΩ ±5%	
R65	Comp., 16 kΩ, ±5%, 1/4 W	6099-3165	75042	BTS, 16 kΩ, ±5%	
R66	Comp, 2.2 kΩ ±5%	6099-2225	75042	BTS, 2.2 kΩ ±5%	5905-723-5251
R67	Comp, 100 Ω ±5%	6099-1105	75042	BTS, 100 Ω ±5%	
R68	Comp, 150 Ω ±5%	6100-1155	01121	RC20GF151J	5905-299-1541
R69	Comp, 750 Ω ±5%	6099-1755	75042	BTS, 750 Ω ±5%	
R70	Comp, 620 Ω ±5%	6099-1625	75042	BTS, 620 Ω ±5%	5905-801-6998
R71	Comp, 16 kΩ ±5%	6099-3165	75042	BTS, 16 kΩ ±5%	
R72 and R73	Comp, 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R80	Comp., 82 kΩ, ±5%, 1/4 W	6099-3825	75042	BTS, 82 kΩ, ±5%	
R94	Comp., 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R101 and R102	Comp, 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R103	Comp, 10 kΩ ±5%	6099-3105	75042	BTS, 10 kΩ ±5%	5905-683-2238
R104	Comp, 510 Ω ±5%	6099-1515	75042	BTS, 510 Ω ±5%	5905-801-8272
R109 and R110	Comp, 10 MΩ ±5%	6099-6105	75042	BTS, 10 MΩ ±5%	
R111 and R112	Comp, 5.1 MΩ ±5%	6099-5515	75042	BTS, 5.1 MΩ ±5%	
R113 and R114	Pot.,comp, 20 kΩ ±10%	6049-0219	01121	SV2031	
R115	Comp., 10 kΩ ±5%	6099-3105	75042	BTS, 10 kΩ ±5%	5905-683-2238
R116	Comp., 130 kΩ ±5%	6099-4135	75042	BTS, 130 kΩ ±5%	
R117 and R118	Comp., 510 Ω, ±5%, 1/4 W	6099-1515	75042	BTS, 510 Ω, ±5%	5905-801-8272

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
TRANSISTORS					
Q1 and Q2	Type 2N4275	8210-1126	07263	Type 2N4275	
Q3 thru Q6	Type 2N3414	8210-1047	24454	Type 2N3414	
Q7 thru Q10	Type 2N3646	8210-1119	07263	Type 2N3646	
Q11 thru Q13	Type 2N4123	8210-1123	04713	2N4123	
Q14	Type 2N3414	8210-1047	24454	Type 2N3414	
Q15	Type 2N5249	8210-1077	24454	Type 2N5249	
Q16	Type 2N4258	8210-1136	07263	Type 2N4258	
Q21	Type 2N3414	8210-1047	24454	Type 2N3414	

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
OSCILLATOR BOARD (P/N 1683-4727) ELECTRICAL REPLACEABLE PARTS					
CAPACITORS					
C1	Plastic, .01 µF ±2% 50 V	4865-2100	74861	11503-TYV	
C2	Plastic, .01 µF ±2% 50 V	4865-2100	74861	11503-TYV	
C3	Plastic, .0733 µF ±2% 50 V	4865-2733	74861	11698-TYV	
C4	Plastic, .0733 µF ±2% 50 V	4865-2733	74861	11698-TYV	
C5	Electrolytic, 2.2 µF ±20% 20 V	4450-4500	56289	150D225X0020A2	5910-976-4604
C6	Ceramic, 39 pF ±10% 500 V	4404-0398	72982	831, 39 pF ±10%	
C8	Ceramic, 0.1 µF +80-20% 100 V	4403-4100	80131	CC63, .1 µF +80-20%	5910-811-4788
C9	Tantalum, 4.7 µF ±20% 10 V	4450-4700	56289	150D465X0015B2	5910-813-8160
DIODES					
CR1	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
INTEGRATED CIRCUITS					
IC1	Type 201 Linear	5432-2010	24446	LM201	
IC2	Type LM301A	5432-1004	12040	LM301A	
RESISTORS					
R1	Pot., comp., 2 kΩ ±10%	6051-2209	07999	2600PC, 2 kΩ ±10%	
R2	Pot., comp., 2 kΩ ±10%	6051-2209	07999	2600PC, 2 kΩ ±10%	
R3	Prec., wire wound 700 Ω ±.5% 1/2 W	6982-3001	24655	6982-3001	
R4	Prec., wire wound 14.3 kΩ ±.1% 1/2 W	6982-5010	24655	6982-5010	
R5	Prec., wire wound 15.92 kΩ ±.1% 1/2 W	6982-5011	24655	6982-5011	
R6	Comp, 33 kΩ ±5% 1/4 W	6099-3335	75042	BTS, 33 kΩ ±5%	
R7	Comp., 30 kΩ ±5%, 1/4 W	6099-3305	75042	BTS, 30 kΩ, ±5%	5905-803-2908
R8	Comp., 10 kΩ ±5%, 1/4 W	6099-3105	75042	BTS, 10 kΩ, ±5%	5905-683-2238
R9	Comp., 470 kΩ ±5%, 1/4 W	6099-1475	75042	BTS, 470 kΩ, ±5%	5905-683-2242
R10	Thermistor 40 kΩ ±10%	6740-1400	02606	BA44V1	
R11	Comp, 10 kΩ ±5% 1/4 W	6099-3105	75042	BTS, 10 kΩ ±5%	5905-683-2238
R12	Comp, 6.2 kΩ ±5% 1/4 W	6099-2625	75042	BTS, 6.2 kΩ ±5%	5905-682-4100
R14	Comp, 1 kΩ ±5% 1/4 W	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6462
R15	Comp, 3.3 kΩ ±5% 1/4 W	6099-2335	75042	BTS, 3.3 kΩ ±5%	5905-681-9969
R17	Comp, 20 kΩ ±5% 1/4 W	6099-3205	75042	BTS, 20 kΩ ±5%	5905-686-3368
R18	Comp, 16 kΩ ±5% 1/4 W	6099-3165	75042	BTS, 16 kΩ ±5%	
R19	Comp, 100 kΩ ±5% 1/4 W	6099-4105	75042	BTS, 100 Ω ±5%	5905-686-3129
R20	Pot.,Comp., 1 kΩ ±10%	6051-2109	02660	2600-PC, 1 kΩ ±10%	
R21	Comp, 2 kΩ ±5% 1/4 W	6099-2205	75042	BTS, 2 kΩ ±5%	5905-279-4629
R23	Comp, 10 kΩ ±5% 1/4 W	6099-3105	75042	BTS, 10 kΩ ±5%	5905-683-2238
RELAYS					
K3S	Relay switch	6090-0800	30874	76586S	
K4S	Relay switch	6090-0800	30874	76586S	
K3L	Relay coil	6090-1130	71707	XU-8242-P	
K4L	Relay coil	6090-1130	71707	XU-8242-P	
TRANSISTORS					
Q2	Type 2N3414	8210-1047	24446	2N3414	5961-989-2749
Q3	Type 2N4125	8210-1125	93916	2N4125	
Q4	Type 2N3414	8210-1047	24446	2N3414	5961-989-2749
Q5	Type 2N1302	8210-1018	96214	2N1302	5960-086-0039
Q7	Type 2N4125	8210-1125	93916	2N4125	

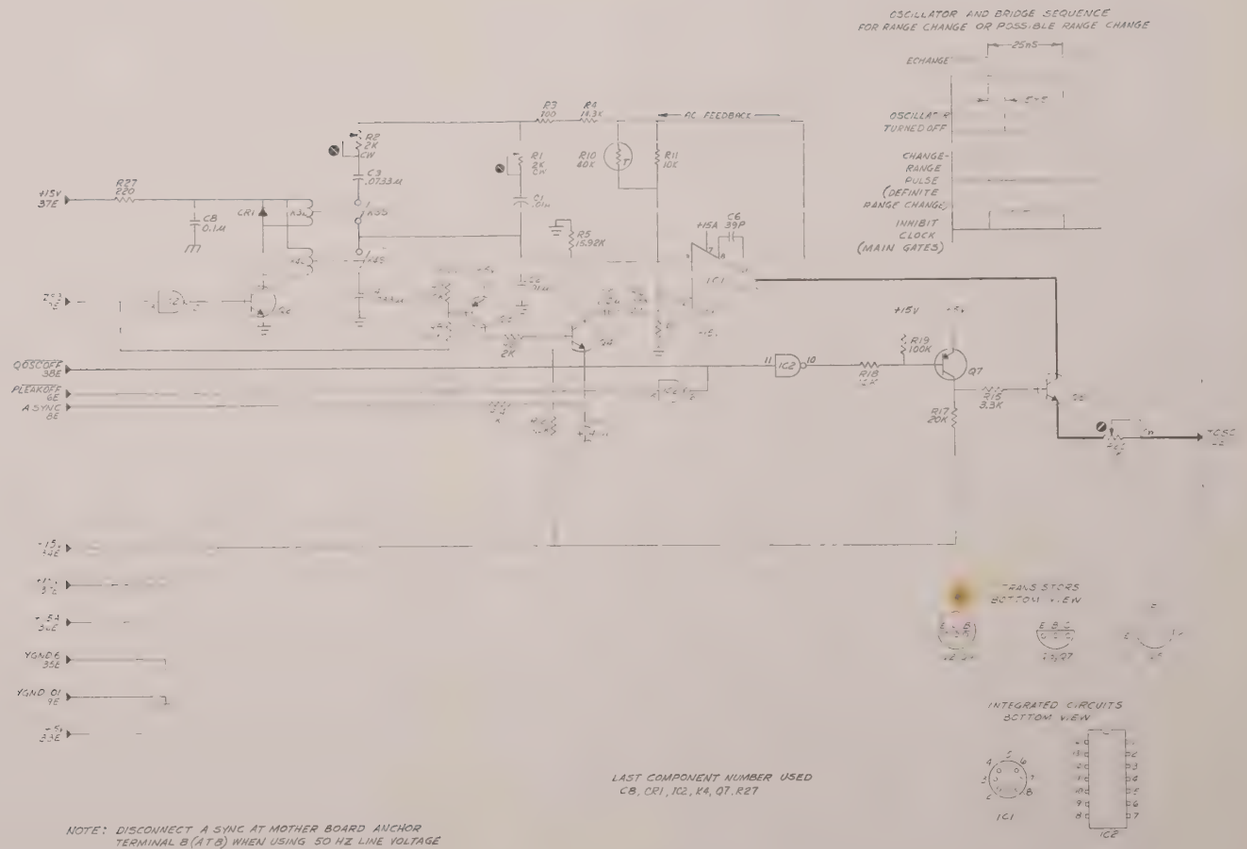


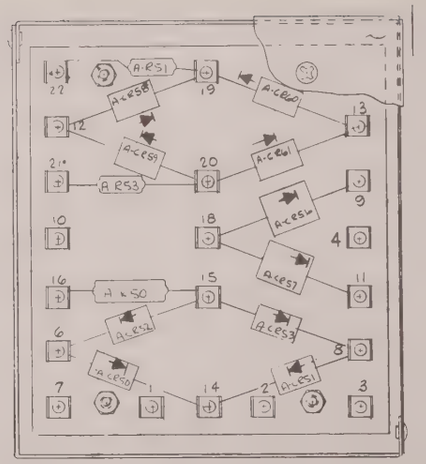
Figure 6-23. Oscillator board schematic, T.

ELECTRICAL PARTS LIST

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
	POWER SUPPLY BOARD (P/N 1683-4715) ELECTRICAL REPLACEABLE PARTS				
CAPACITORS					
C1	Ceramic, 0.22 µF ±20%	4400-2052	80183	5C13, .22 µF ±20%	5910-974-5694
C2	Tantalum, 2000 µF +150-10%	4450-6106	37942	TT, 2000 µF +150-10%	
C3	Tantalum, 4.7 µF ±20%	4450-4700	56289	150D465X0015B2	5910-813-8160
C4	Ceramic, .05 µF +80-20%	4403-3500	01121	40-503W	5910-882-7321
C5	Tantalum, 47 µF ±20%	4450-5614	56289	150D476X0020R2	
C6	Tantalum, 4.7 µF ±20%	4450-4700	56289	150D465X0015B2	5910-813-8160
C7	Tantalum, 47 µF ±20%	4450-5614	56289	150D476X0020R2	
C8	Ceramic, .05 µF +80-20%	4403-3500	01121	40-503W	5910-882-7321
C9	Electrolytic, 680 µF +150-10%	4450-6015	37942	TT, 680 µF +150-10%	
C10	Tantalum, 47 µF ±20%	4450-5614	56289	150D476X0020R2	
DIODES					
CR1 and CR2	Type 1N4009	6082-1014	24446	1N695	
CR4 and CR5	Type 1N4009	6082-1012	24446	1N4009	5961-892-8700
CR6	Type 1N4009	6083-1009	07910	1N957B	
CR7	Type 1N4009	6082-1012	24446	1N4009	5961-892-8700
CR9 and CR10	Type 1N4009	6082-1014	24446	1N695	
CR11 and CR12	Type 1N4009	6082-1012	24446	1N4009	5961-892-8700
RESISTORS					
R3	Comp., 3.3 kΩ ±5%	6099-2335	75042	BTS, 3.3 kΩ ±5%	5905-681-9969
R5	Comp., 33 Ω ±5%	6099-0335	75042	BTS, 33 Ω ±5%	
R6	Comp., 47 Ω ±5%	6099-0475	75042	BTS, 47 Ω ±5%	
R8	Comp., 11 kΩ ±5%	6099-3115	75042	BTS, 11 kΩ ±5%	
R9	Film, 1 kΩ ±1%	6250-1100	75042	CEA, 1 kΩ ±1%	5905-581-6915
R10	Film, 2 kΩ ±1%	6250-1200	75042	CEA, 2 kΩ ±1%	5905-577-6614
R11	Low-power wire wound, REW-3C, 82 Ω ±5%	6760-8825	75042	BWH, .82 Ω ±5%	
R12	Comp., 3.3 kΩ ±5%	6099-2335	75042	BTS, 3.3 kΩ ±5%	5905-681-9969
R14	Comp., 360 Ω ±5%	6099-1365	75042	BTS, 360 Ω ±5%	
R15	Comp., 4.7 Ω ±5%	6099-9475	75042	BTS, 4.7 Ω ±5%	
R16	Comp., 10 kΩ ±5%	6099-3105	75042	BTS, 10 kΩ ±5%	
R17	Comp., 47 Ω ±5%	6099-0475	75042	BTS, 47 Ω ±5%	
R18	Comp., 10 kΩ ±5%	6099-3105	75042	BTS, 10 kΩ ±5%	5905-683-2238
R19	Film, 3.01 kΩ ±1%	6250-1301	75042	CEA, 3.01 kΩ ±1%	5905-702-5974
R20	Comp.,750 Ω ±5%	6099-1755	75042	BTS, 750 Ω ±5%	
R22	Comp., 4.3 kΩ ±5%	6099-2435	75042	BTS, 4.3 kΩ ±5%	
R23	Pot.,wire wound, 1 kΩ ±10%	6051-2109	02660	2600-PC, 1 kΩ ±10%	
R24	Film, 3.16 kΩ ±1%	6350-1316	75042	CEB, 3.16 kΩ ±1%	5905-583-6902
R25	Comp., 4.7 kΩ ±5%	6099-2475	75042	BTS, 4.7 kΩ ±5%	5905-686-9992
R26	Comp., 10 kΩ ±5%	6099-3105	75042	BTS, 10 kΩ ±5%	5905-683-2238
R27	Comp., 36 kΩ ±5%	6099-3365	75042	BTS, 36 kΩ ±5%	5905-683-7726
R28	Film, 5.11 kΩ ±1%	6350-1511	75042	CEB, 5.11 kΩ ±1%	
R29	Pot.,wire wound, 500 Ω ±10%	6051-1509	02660	2600 PC, 500 Ω ±10%	
R30	Film, 4.87 kΩ ±1%	6450-1487	75042	CEC, 4.87 kΩ ±1%	
R31	Comp., .47 Ω ±5%	6099-0475	75042	BTS, 47 Ω ±5%	
R32	Comp., 360 Ω ±5%	6099-1365	75042	BTS, 360 Ω ±5%	
R33	Comp., 4.7 Ω ±5%	6099-9475	75042	BTS, 4.7 Ω ±5%	
R34	Comp., 300 Ω ±5%	6100-1305	01121	RC20GF301J	5905-279-5481
R35	Low-power, wire wound, 1.5 Ω ±10%	6760-9159	75042	BWH, 1.5 Ω ±10%	
R36	Comp., 3.3 kΩ ±5%	6099-2335	75042	BTS, 3.3 kΩ ±5%	5905-681-9969
R37	Low-power, wire wound, 82 Ω ±5%	6760-8825	75042	BWH, .82 Ω ±5%	
R39	Comp., 12 kΩ ±5%	6100-3125	01121	RC20GF123J	5905-279-3502
R40	Comp., 1.2 kΩ ±5%	6099-2125	75042	BTS, 1.2 kΩ ±5%	
R41	Comp., 150 Ω ±5%	6099-1155	75042	BTS, 150 Ω ±5%	
R42	Comp., 15 kΩ ±5%	6099-3155	75042	BTS, 15 kΩ ±5%	5905-681-8818
R43	Comp., 20 Ω ±5%	6120-0205	01121	HB, 20 Ω ±5%	
R44	Comp., 620 Ω ±5%	6099-1625	75042	BTS, 620 Ω ±5%	
R45	Comp., 2.7 kΩ ±5%	6099-2275	75042	BTS, 2.7 kΩ ±5%	
R46	Comp., 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R47	Film, 5.11 kΩ ±1%	6350-1511	75042	CEB, 5.11 kΩ ±1%	
R48	Film, 4.64 kΩ ±1%	6450-1464	75042	CEC, 4.64 kΩ ±1%	
R49	Comp., 9.1 kΩ ±5%	6099-2915	75042	BTS, 9.1 kΩ ±5%	5905-279-4619
R50	Comp., 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422
R51	Comp., 2 kΩ ±5%	6099-2205	75042	BTS, 2 kΩ ±5%	5905-686-3370
R52	Comp., 300 Ω ±5%	6100-1305	01121	RC20GF301J	5905-279-5481

ELECTRICAL PARTS LIST (cont)

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
TRANSISTORS					
Q1 and Q2	Type 2N3905	8210-1114	04713	2N3905	
Q3 thru Q6	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749
Q7	Type 2N697	8210-1040	49956	2N697	5961-752-0150
Q8	Type 2N3905	8210-1114	04713	2N3905	
Q9	Type 2N4250	8210-1135	07263	2N4250	
Q10	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749
Q11	Type 2N3903	8210-1132	04713	2N3903	
Q12	Type 2N1131	8210-1025	96214	2N1131	5961-081-8365
Q13	Type 2N3905	8210-1114	04713	2N3905	
Q19	Type 40250	8210-1095	79089	40250	
Q21	Type 2N3740	8210-1121	04713	2N3740	
Q22	Type 2N3905	8210-1114	04713	2N3905	
Q23 thru Q25	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749



NOTE

Refer to the list on page 6-4 for the transformer and transistor assembly parts.

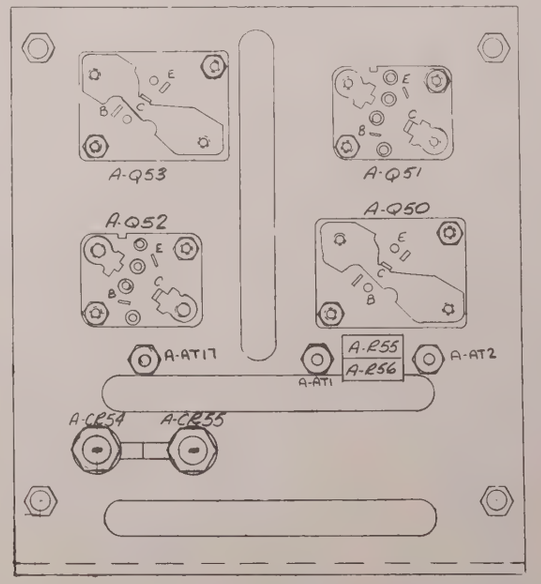


Figure 6-24. Transformer assembly and transistor bracket assembly, V.

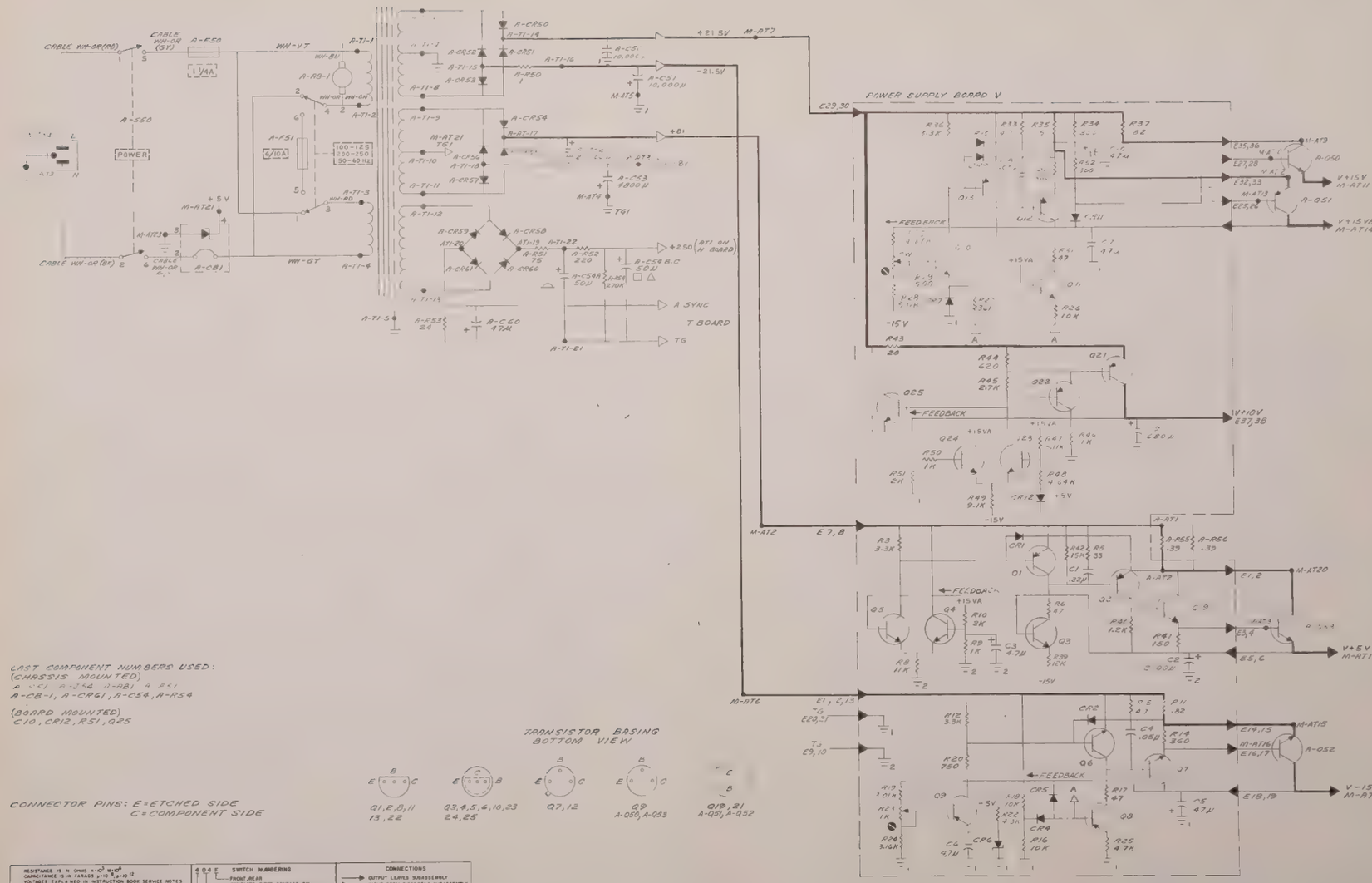


Figure 6-25. Power supply board and line-voltage circuit schematic, V.

ELECTRICAL PARTS LIST

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
	Y-BRIDGE BOARD (P/N 1683-4746) ELECTRICAL REPLACEABLE PARTS				
	CAPACITORS				
C1	Plastic, 2 µF ±5%	4860-1700	24655	4860-1700	
C3	Ceramic, .01 µF +80-20%	4401-3100	80131	CC61, .01 µF +80-20%	5910-974-5697
C4	Tantalum, 4.7 µF ±20%	4450-4700	56289	150D465X0015B2	5910-813-8160
C5	Ceramic, .02 µF +80-20%	4402-3200	01121	35-203W	
C6	Tantalum, 68 µF ±20%	4450-5615	80183	150D686X0015R2	
C7	Tantalum, 68 µF ±20%	4450-5615	80183	150D686X0015R2	
C8	Tantalum, 330 µF ±20%	4450-5707	37942	TT, 330 µF ±20%	
C9	Tantalum, 180 µF ±20%	4450-5617	56289	150D187X0006R2	
C10	Ceramic, .02 µF +80-20%	4402-3200	01121	35-203W	5910-974-5698
C11	Ceramic, .02 µF, +80-20%, 100 V	4402-3200	01121	35-203W	5910-974-5698
C12	Ceramic, 4.7 pF ±.5% NPO	4400-2700	72982	C1, 4.7 pF ±.5% NPO	5910-914-2603
C13	Tantalum, 15 µF ±20%	4450-5200	56289	150D156X0020B2	5910-855-6335
C14	Ceramic, .02 µF +80-20%	4402-3200	01121	35-203W	5910-974-5698
C16 and C17	Tantalum, 68 µF ±20%	4450-5615	80183	150D686X0015R2	
C18	Ceramic, 1000 pF +80-20%	4404-2119	72982	831, 1000 pF +80-20%	5910-075-9607
C20	Tantalum, 15 µF ±20%	4450-5200	56289	150D156X0020B2	5910-855-6335
C21	Ceramic, 2200 pF, ±10%, 500 V	4405-2228	72982	811, .0022 µF, ±10%	
C23	Tantalum, 68 µF ±20%	4450-5615	80183	150D686X0015R2	
C25	Tantalum, 68 µF ±20%	4450-5615	80183	150D686X0015R2	
C26	Ceramic, 4.7 pF, ±0.5%, 500 V, NPO	4400-2700	72982	C1, 4.7 pF, 0.5%	
C27	Ceramic, Tubular, 3.3 pF, ±5%, 500 V	4400-0330	78488	GA, 3.3 pF, ±5%	
C28	Ceramic, 6.8 pF ±5%	4400-0680	78488	GA, 6.8 pF ±5%	5910-914-2603
C29	Ceramic, Tubular, 1.8 pF, ±5%, 500 V	4400-0180	78488	GA, 1.8 pF, ±5%	
C30 and C31	Ceramic, 1 µF ±20%	4400-2070	80183	5C13, 1 µF ±20%	5910-083-6445
C32	Ceramic, 2.2 µF ±20%	4400-2080	80183	5C13, 2.2 µF ±20%	
C33	Tantalum, 4.7 µF ±20%	4450-4700	56289	150D465X0015B2	5910-813-8160
C36	Ceramic, 1 µF ±20%	4400-2070	80183	5C13, 1 µF ±20%	5910-083-6445
C37 and C38	Ceramic, 2.2 µF ±20%	4400-2080	80183	5C13, 2.2 µF ±20%	
C39	Trimmer, 2-8 pF	4910-2033	72982	538-006, 2.8 pF	
	DIODES				
CR2 and CR3	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR7 and CR8	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR13 thru CR24	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR26 and CR27	Type 1N645	6082-1016	24446	1N645	5961-087-6047
CR28 and CR29	Type 1N759A	6083-1014	81349	1N759A	5961-846-9157
CR30 and CR31	Type 1N3604	6082-1001	24446	1N3604	5961-995-2199
CR32 and CR33	Type 1N759A	6083-1014	81349	1N759A	5961-846-9157
CR34	Type 1N957A	6082-1001	24446	1N3604	5961-995-2199
CR37 thru CR39	Type 1N4009	6082-1012	24446	1N4009	5961-892-8700
	INTEGRATED CIRCUITS				
IC1	Digital	5431-9362	96214	SN15836N	
IC2	Digital	5431-9622	96214	SN15862N	
IC3	Digital	5431-9362	96214	SN15836N	
	RELAYS				
K1L and K2L	Reed switch and coil	6090-1300	14413	401-4AR-12	
K3L thru K9L	Reed coil	6090-1130	71707	XU-8242-P	
K11L and K12L	Reed coil	6090-1130	71707	XU-8242-P	
K1S and K2S	Reed switch and coil	6090-1300	14413	401-4AR-12	
K4S thru K9S	Reed switch	6090-0800	30874	76586S	
K11S and K12S	Reed switch	6090-0800	30874	76586S	
K3S	Reed switch	6090-1165			

ELECTRICAL PARTS LIST (cont)

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
	RESISTORS				
R3	Comp., 620 Ω ±5%	6099-1625	75042	BTS, 620 Ω ±5%	5905-801-6998
R4	Comp., 7.5 kΩ ±5%	6099-2755	75042	BTS, 7.5 kΩ ±5%	
R5	Comp., 47 Ω ±5%	6099-0475	75042	BTS, 47 Ω ±5%	5905-809-8596
R6	Comp., 47 kΩ ±5%	6099-3475	75042	BTS, 47 kΩ ±5%	5905-683-2242
R7	Comp., 62 kΩ ±5%	6099-3625	75042	BTS, 62 kΩ ±5%	
R8	Comp., 750 Ω ±5%	6099-1755	75042	BTS, 750 Ω ±5%	
R9	Comp., 7.5 Ω ±5%	6099-9755	75042	BTS, 7.5 Ω ±5%	
R10 and R11	Comp., 620 Ω ±5%	6099-1625	75042	BTS, 620 Ω ±5%	5905-801-6998
R12	Comp., 100 Ω ±5%	6099-1105	75042	BTS, 100 Ω ±5%	
R13	Wire wound, 50 kΩ ±.01%	6983-5036	24655	6983-5036	
R15 and R16	Wire wound, 250 kΩ ±.01%	6984-6007	24655	6984-6007	
R17	Wire wound, 49.95 kΩ ±.01%	6983-5035	24655	6983-5035	
R18	Comp.,7.5 kΩ ±5%	6099-2755	75042	BTS, 7.5 kΩ ±5%	
R19	Comp., 24 kΩ ±5%	6099-3245	75042	BTS, 24 kΩ ±5%	
R20 and R21	Comp., 51 kΩ ±5%	6099-3515	75042	BTS, 51 kΩ ±5%	5905-682-4103
R22	Comp., 20 Ω ±5%, 1/4 W	6099-0205	75042	BTS, 20 kΩ, ±5%	
R23	Wire wound, 5.0005 kΩ ±.01%	6983-4041	24655	6983-4041	
R26	Comp., 750 Ω ±5%	6099-1755	75042	BTS, 750 Ω ±5%	
R27	Comp., 20 Ω, ±5%	6099-0205	75042	BTS, 20 Ω ±5%	
R28	Comp., 750 Ω ±5%	6099-1755	75042	BTS, 750 Ω ±5%	
R29	Comp., 240 Ω ±5%	6099-1245	75042	BTS, 240 Ω ±5%	
R30	Comp., 130 Ω ±5%	6099-1135	75042	BTS, 130 Ω ±5%	5905-807-0269
R31	Wire wound, .01 Ω ±.1%	P/O resistor asm 1683-2220			
R32	Wire wound, .09 Ω ±.1%	P/O resistor asm 1683-2220			
R33	Wire wound, 0.9 Ω ±0.1%	6982-9000	24655	6982-9000	
R34	Wire wound, 8.9982 Ω ±.01%	6983-1002	24655	6983-1002	
R35	Wire wound, 90 Ω ±.01%	6983-2002	24655	6983-2002	
R36	Wire wound, 900 Ω ±.01%	6983-3013	24655	6983-3013	
R37	Wire wound, 111.11 Ω ±.01%	6983-3014	24655	6983-3014	
R38	Wire wound, 900 Ω ±.01%	6983-3013	24655	6983-3013	
R39	Comp., 91 Ω ±5%	6099-0915	75042	BTS, 91 Ω ±5%	
R40	Comp., 7.5 kΩ ±5%	6099-2755	75042	BTS, 7.5 kΩ ±5%	
R41	Comp., 24 kΩ ±5%	6099-3245	75042	BTS, 24 kΩ ±5%	
R42 and R43	Comp., 51 kΩ ±5%	6099-3515	75042	BTS, 51 kΩ ±5%	5905-682-4103
R44	Wire wound, 1.474 kΩ ±.01%	6983-4039	24655	6983-4039	
R45	Wire wound, 14.740 kΩ ±.01%	6983-5037	24655	6983-5037	
R46	Wire wound, 66.327 kΩ ±.01%	6984-5007	24655	6984-5007	
R47	Comp., 16 kΩ ±5%	6099-3165	75042	BTS, 16 kΩ ±5%	
R49	Comp., 750 Ω ±5%	6099-1755	75042	BTS, 750 Ω ±5%	
R50	Comp., 680 Ω ±5%	6099-1685	75042	BTS, 680 Ω ±5%	
R51	Comp., 91 Ω ±5%	6099-0915	75042	BTS, 91 Ω ±5%	
R52	Comp., 240 Ω ±5%	6099-1245	75042	BTS, 240 Ω ±5%	
R53	Comp., 130 Ω ±5%	6099-1135	75042	BTS, 130 Ω ±5%	5905-807-0269
R54	Comp., 120 Ω ±5%, 1/4 W	6099-1125	75042	BTS, 120 kΩ, ±5%	
R57	Comp., 10 kΩ ±5%	6099-3105	75042	BTS, 10 kΩ ±5%	5905-683-2238
R58	Comp., 5.1 kΩ ±5%	6099-2515	75042	BTS, 5.1 kΩ ±5%	5905-683-2241
R59	Comp., 750 Ω ±5%	6099-1755	75042	BTS, 750 Ω ±5%	
R60	Wire wound, 66.327 kΩ ±.01%	6984-5007	24655	6984-5007	
R61	Comp., 200 Ω ±5%	6099-1205	75042	BTS, 200 Ω ±5%	5905-683-2239
R70 and R71	Comp., 220 Ω ±5%	6099-1225	75042	BTS, 220 Ω ±5%	5905-683-2240
R72	Comp., 36 Ω ±5%	6100-0365	01121	RC20GF360J	5905-279-1885
R73	Comp., 8.2 kΩ ±5%	6099-2825	75042	BTS, 8.2 kΩ ±5%	
R74	Comp., 240 kΩ ±5%	6099-4245	75042	BTS, 240 kΩ ±5%	
R75	Comp., 12 kΩ ±5%	6099-3125	75042	BTS, 12 kΩ ±5%	
R76	Comp., 8.2 kΩ ±5%	6099-2825	75042	BTS, 8.2 kΩ ±5%	
R77 and R78	Comp., 220 kΩ ±5%	6099-4225	75042	BTS, 220 kΩ ±5%	
R80	Comp., 4.7 kΩ ±5%, 1/4 W	6099-2475	75042	BTS, 4.7 kΩ, ±5%	5905-686-9992
R82	Comp., 5.1 kΩ ±5%	6099-2515	75042	BTS, 5.1 kΩ ±5%	5905-683-2241
R83	Comp., 8.2 kΩ ±5%	6099-2825	75042	BTS, 8.2 kΩ ±5%	
R84	Comp., 22 kΩ ±5%	6099-3225	75042	BTS, 22 kΩ ±5%	5905-687-0002
R86	Comp., 1 kΩ ±5%	6099-2105	75042	BTS, 1 kΩ ±5%	5905-681-6422

ELECTRICAL PARTS LIST (cont)

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
	TRANSISTORS				
Q1	Type 2N5249	8210-1077	24454	2N5249	
Q2	Type #4JX16A733	8210-1083	24454	#47X16A733	
Q3	Type 2N4250	8210-1135	07263	2N4250	
Q4	Type 2N4384	8210-1131	56289	2N4384	
Q5	Type TD-100	8210-1130	56289	TD-100	
Q7	Type 2N4250	8210-1135	07263	2N4250	
Q8	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749
Q9	Type 2N4123	8210-1123	04713	2N4123	
Q10	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749
Q14	Type TD-100	8210-1130	56289	TD-100	
Q16	Type 2N4250	8210-1135	07263	2N4250	
Q18	Type 2N4123	8210-1123	04713	2N4123	
Q19	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749
Q21 thru Q30	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749
Q31	Type 2N4123	8210-1123	04713	2N4123	
Q32	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749
Q33	Type 2N5249	8210-1077	24454	2N5249	
Q36	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749
Q37	Type 2N5249	8210-1077	24454	2N5249	

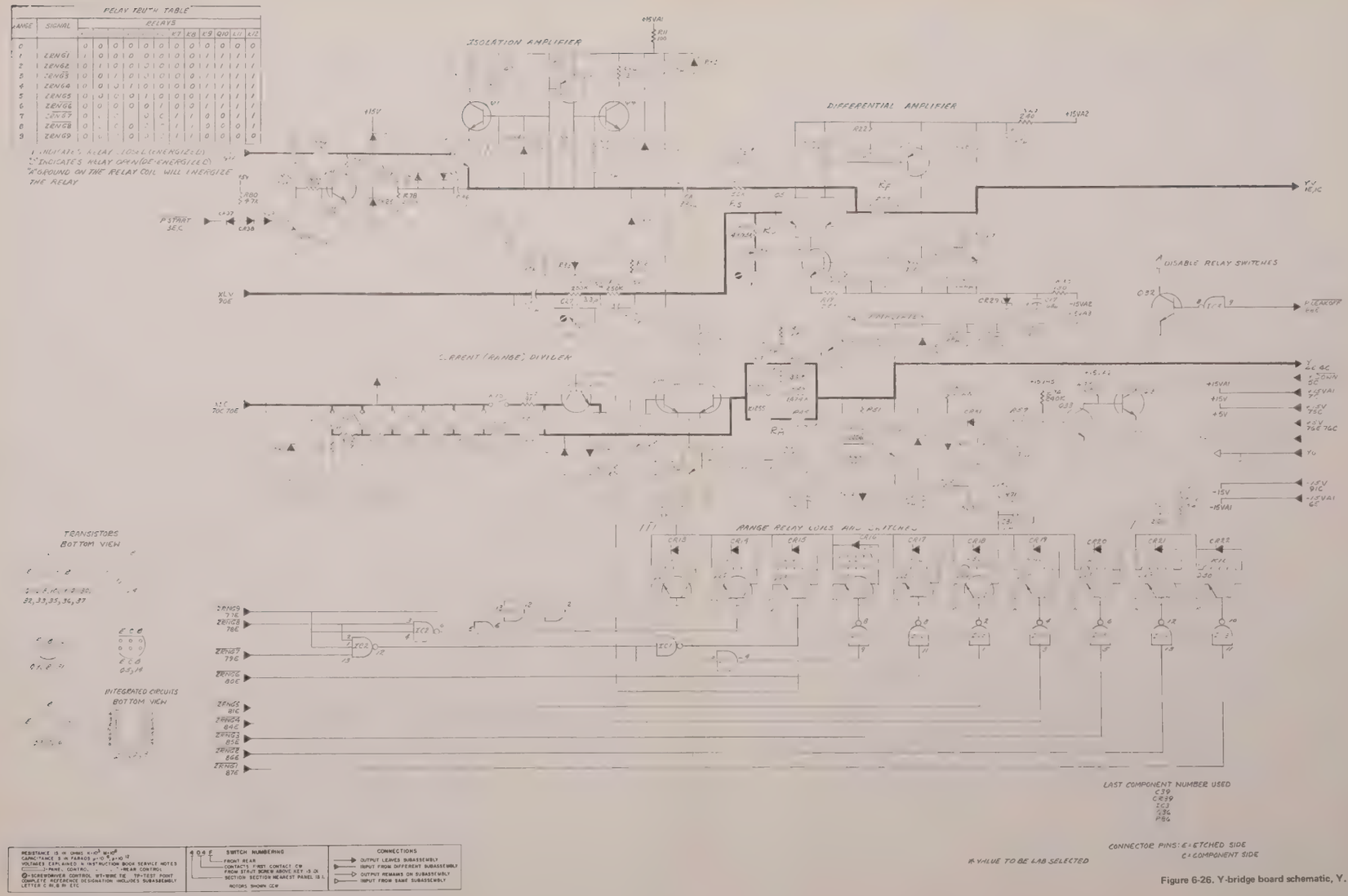


Figure 6-26. Y-bridge board schematic, Y.

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
	CONTROL BOARD (P/N 1683-4775) ELECTRICAL REPLACEABLE PARTS				
CAPACITORS					
C1	Tantalum, 1 µF ±20%	4450-4300	56289	150D105X0035A2	
C2	Tantalum, 180 µF ±20%	4450-5617	56289	150D187X0006R2	
C3	Ceramic, 2.2 µF ±20% .25 V	4400-2080	80183	5C13, 2.2 µF ±20%	
DIODES					
CR1 and CR2	Type 1N995	6082-1002	80368	1N995	5961-193-6762
INTEGRATED CIRCUITS					
IC1 and IC2	Digital	5431-9442	96214	SN15842N	
IC3 and IC4	Digital	5431-9462	96214	SN15846N	
IC5 thru IC12	Digital	5431-9442	96214	SN15842N	
IC13 thru					
IC16	Digital	5431-9622	96214	SN15862N	
IC17	Digital	5431-9362	96214	SN15836N	
IC18	Digital	5431-9442	96214	SN15842N	
IC19 and					
IC20	Digital	5431-9322	96214	SN15832N	
IC21	Digital	5431-9462	96214	SN15846N	
IC22 and					
IC23	Digital	5431-9362	96214	SN15836N	
IC24	Digital	5431-9442	96214	SN15842N	
IC25 thru					
IC28	Digital	5431-9622	96214	SN15862N	
IC29	Digital	5431-9442	96214	SN15842N	
IC30	Digital	5431-9362	96214	SN15836N	
RESISTORS					
R1 thru R15	Comp. 5.6 kΩ ±5%	6099-2565	75042	BTS, 5.6 kΩ ±5%	5905-691-0195
R17 thru R24	Comp. 5.6 kΩ ±5%	6099-2565	75042	BTS, 5.6 kΩ ±5%	5905-691-0195
R26 thru R32	Comp. 5.6 kΩ ±5%	6099-2565	75042	BTS, 5.6 kΩ ±5%	5905-691-0195
R33	Comp. 249 Ω ±1%	6350-0249	75042	CEB, 249 Ω ±1%	
R34	Film, 63.3 kΩ ±1%	6250-2633	75042	CEA, 63.3 kΩ ±1%	
R35	Comp. 2 kΩ ±5%	6099-2205	75042	BTS, 2 kΩ ±5%	5905-686-3370
R37	Comp. 510 Ω ±5%	6099-1515	75042	BTS, 510 Ω ±5%	5905-801-8272
R38	Comp., 130 Ω ±5%	6099-1135	75042	BTS, 130 Ω ±5%	5905-807-0269
TRANSISTORS					
Q1	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749

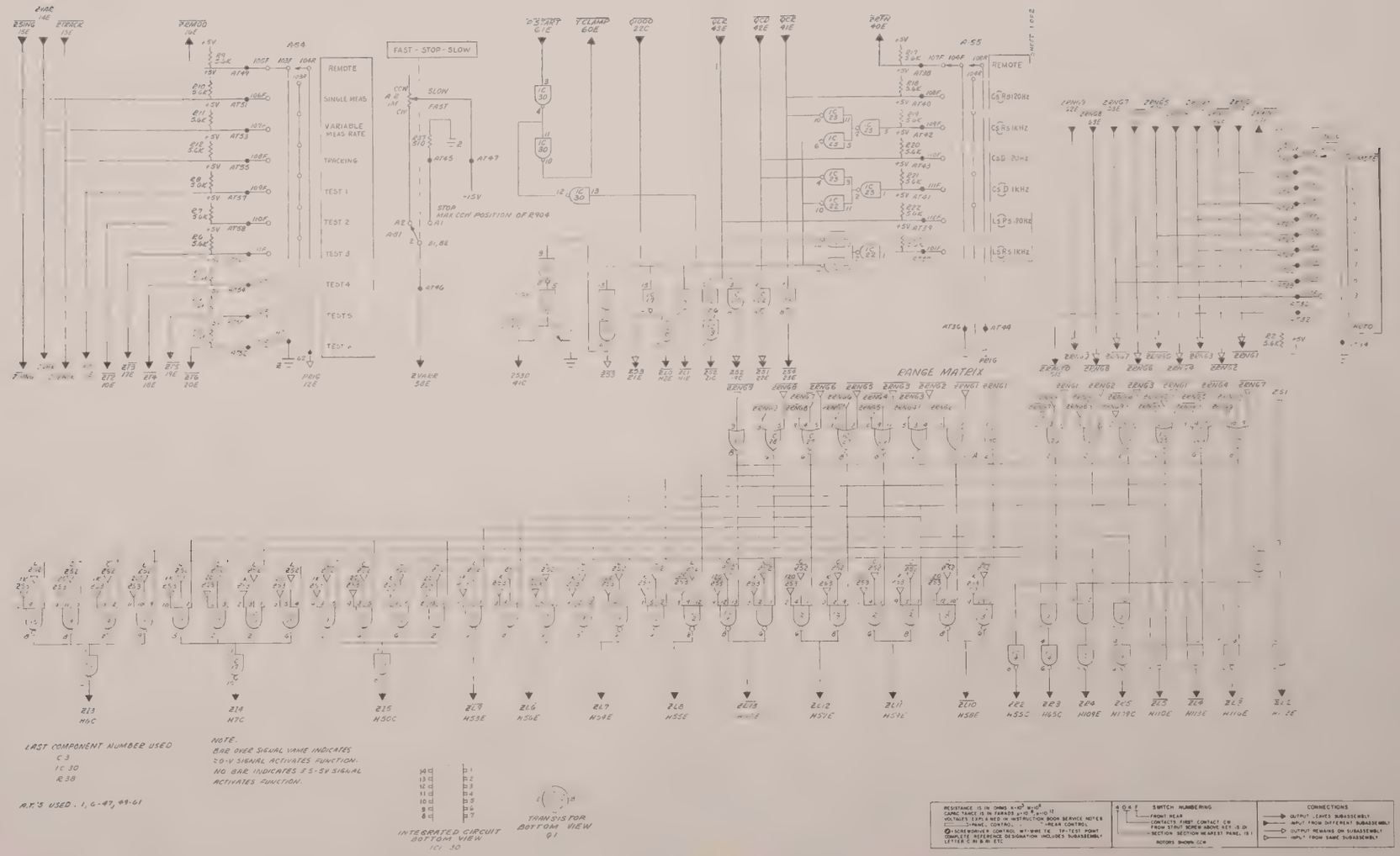


Figure 6-27. Control board schematic (sheet 1 of 2), Z.

Rotary switch sections: The first digit of the contact number refers to the section. The section nearest the panel is 1, the next section back is 2, etc. The next two digits refer to the contact. Contact 01 is the first position clockwise from a strut screw (usually the screw above the locating key), and the other contacts are numbered sequentially (02, 03, 04, etc), proceeding clockwise around the section. A suffix F or R indicates that the contact is on the front or rear of the section, respectively.

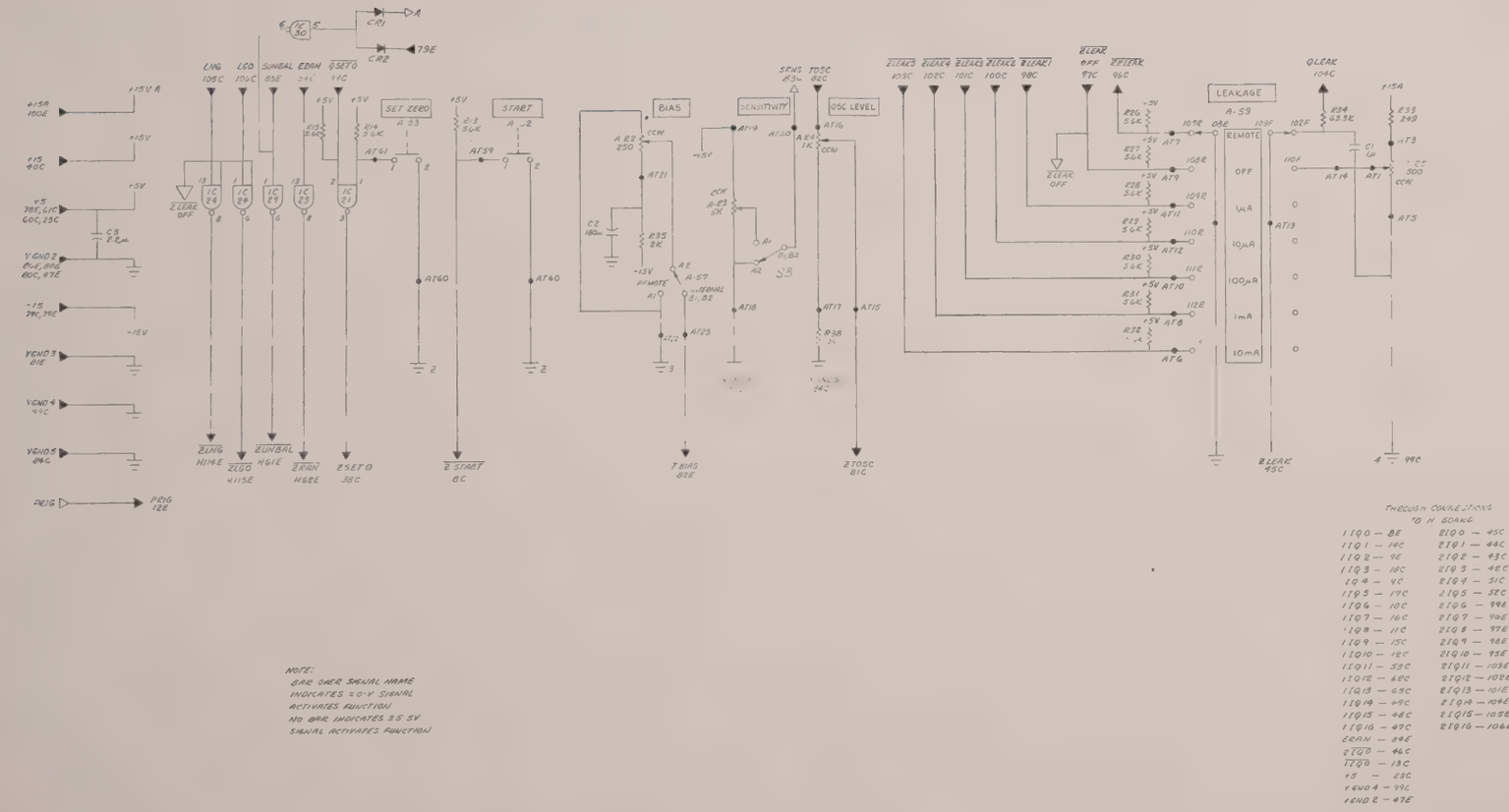
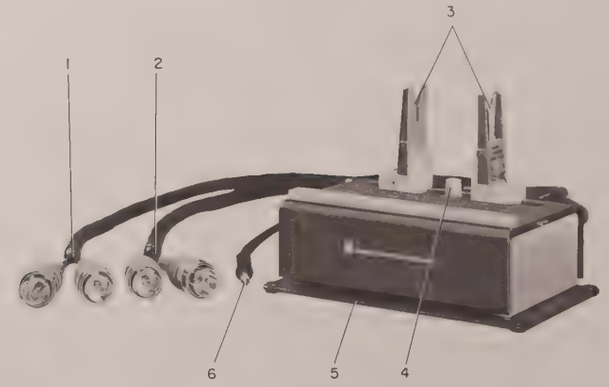


Figure 6-28. Control board schematic (sheet 2 of 2), Z.

MECHANICAL PARTS LIST

Qty	Fig Ref	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
1	1	Cable asm. - includes	1683-0210	24655	1683-0210	
2		Locking cable asm.	0874-4583	24655	0874-4583	
1	2	Cable asm. - includes	1683-0220	24655	1683-0220	
2		Locking cable asm.	0874-4583	24655	0874-4583	
2	3	Connector, clip, J101 + J103	4210-1030	24655	4210-1030	
1	4	Bushing, J102	4150-0900	24655	4150-0900	
1	5	Base plate	1680-8040	24655	1680-8040	
1	6	Plug asm.	8160-0944	24655	8160-0970	



Rotary switch sections: The first digit The section nearest the panel is 1, the next section back is 2, etc. The next two digits refer to the contact. Contact 01 is the first position clockwise from a strut screw (usually the screw above the locating key), and the other contacts are numbered sequentially (02, 03, 04, etc), proceeding clockwise around the section. A suffix F or R indicates that the contact is on the front or rear of the section, respectively.

ELECTRICAL PARTS LIST

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
	1683-P1 TEST FIXTURE ELECTRICAL REPLACEABLE PARTS				
RESISTORS					
R1 and R2	Comp., 100 Ω ±5%	6099-1105	75042	BTS, 100 Ω ±5%	
PLUGS					
PL101	Plug asm.	8160-0944	24655	8160-0944	
SWITCH					
S101	Pushbutton, single	7870-1512	91929	BA-2RB	

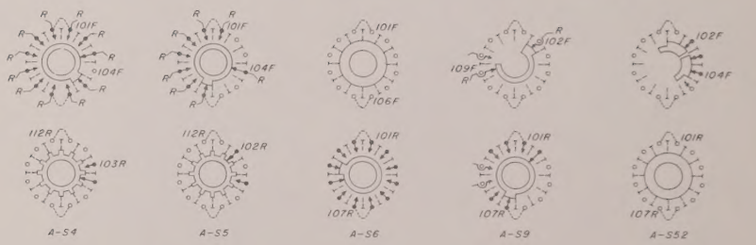


Figure 6-29. Switch diagram.

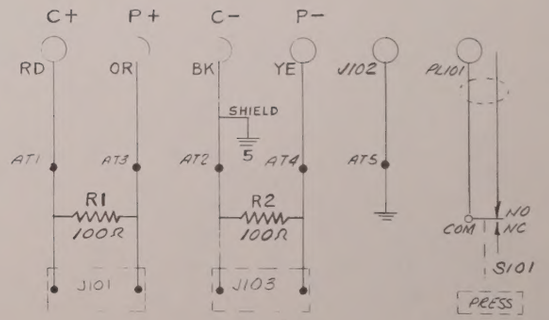


Figure 6-30. 1683-P1 Test Fixture schematic.

GR874® COAXIAL COMPONENTS

GR874 CABLE CONNECTORS

APPLICABLE CABLE TYPES		CONNECTOR TYPE	CABLE	CABLE LOCKING	PANEL FLANGED	PANEL LOCKING	PANEL LOCKING RECESSED	PANEL LOCKING (KEYED)
		874-A2	-CA	-CLA	-PBA	-PLA	-PRLA	-PBRLA
50-OHM		RG-8A/U RG-9B/U RG-10A/U RG-87A/U RG-116/U RG-156/U RG-165/U RG-166/U RG-213/U RG-214/U RG-215/U RG-225/U RG-227/U	-C8A	-CL8A	-PB8A	-PL8A	-PRL8A	-PBRL8A
NON-50-OHM		RG-11A/U RG-12A/U RG-13A/U RG-63B/U RG-79B/U RG-89/U RG-144/U RG-146/U RG-149/U RG-216/U						
50-OHM		874-A3 RG-29/U RG-55/U (series) RG-58/U (series) RG-141A/U RG-142A/U RG-159/U RG-223/U	-C58A	-CL58A	-PB58A	-PL58A	-PRL58A	-PBRL58A
NON 50-OHM		RG-59/U RG-62/U (series) RG-71B/U RG-140/U RG-210/U	-C62A	-CL62A	-PB62A	-PL62A	-PRL62A	PBRL62A
50-OHM		RG-174/U RG-188/U RG-316/U	-C174A	-CL174A	-PB174A	-PL174A	-PRL174A	-PBRL174A
NON 50-OHM		RG-161/U RG-179/U RG-187/U						

Example: For a locking cable connector for RG-8A/U, order Type 874-CL8A.

MISCELLANEOUS COAXIAL CONNECTORS

CONNECTOR TYPE	TYPE NO.	USED WITH
Basic	874-B	50-ohm air line
Basic Locking	874-BBL	50-ohm air line
Panel Locking	874-PLT	Wire lead
Panel Locking Recessed	874-PRLT	Wire lead
Panel Locking Feedthrough	874-PFL	Type 874 patch cords

CONNECTOR ASSEMBLY TOOLS

TYPE 874-	FUNCTION
TOK	Tool Kit
TOS8	Crimping Tool
TO8	Crimping Tool

GR874 ADAPTORS

TO TYPE		TYPE 874
APC-7		QAP7L*
BNC	plug	QBJA
	jack	QBJL* QBPA
C	plug	QCJA*
	jack	QCJL* QCP
GR900		Q900L*
HN	plug	QHJA
	jack	QHPA
LC	plug	QLJA QLPA
LT	plug	QLTP
	jack	QLTJ
Microdot	plug	QMDJ
	jack	QMDJL* QMDP
N	plug	QNJA
	jack	QNJL* QNP QNPL*
SMA	plug	QMMJ
	jack	QMMJL* QMMP QMMPL*
SC (Sandia)	plug	QSCJ
	jack	QSCJL* QSCP
TNC	plug	QTNJ
	jack	QTNJL* QTNP
UHF	plug	QUJ
	jack	QUJL* QUP
GR274 (Binding post pair)	plug jack	777-Q3 274-Q2

*Locking GR874 Connector

Example: To connect Type 874 to a type-N jack, order Type 874-QNP

OTHER COAXIAL ELEMENTS

TYPE 874-	DESCRIPTION	TYPE 874-	DESCRIPTION
A2	50-Ω cable (low-loss)	MB	coupling probe
A3	50-Ω cable	MR, MRL, MRAL	mixer-rectifier
D20L, D50L	20-, 50-cm adjustable stubs	R20A, R20LA	patch cord, double shield
EL, EL-L	90° ell	R22A, R22LA	patch cord, double shield
F185L	185-MHz low-pass filter	R33, R34	patch cord, single shield
F500L	500-MHz low-pass filter	T, TL	tee
F1000L	1000-MHz low-pass filter	TPD, TPDL	power divider
F2000L	2000-MHz low-pass filter	U	U-line section
F4000L	4000-MHz low-pass filter	UBL	balun
FBL	bias insertion unit	VCL	variable capacitor
G3, G3L, G6, G6L, G10, G10L, G14, G14L	3-, 6-, 10-, 14-, and 20-dB attenuators	VI	voltmeter indicator
G20, G20L		VQ, VQL	voltmeter detector
GAL	adjustable attenuator	VR, VRL	voltmeter rectifier
JR	rotary joint	W100	100-Ω termination
K, KL	coupling capacitor	W200	200-Ω termination
L10, L10L	10-, 20-, and 30-cm rigid air lines	W50B, W50BL	50-Ω termination
L20, L20L		WN, WN3, WNL	short-circuit terminations
L30, L30L		WO, WO3, WOL	open-circuit terminations
LAL	35-58 cm adjustable line	X	insertion unit
LK10L, LK20L	constant-Z adjustable lines	XL	series inductor
LR	radiating line	Z	stand
LTL	trombone constant-Z line	-9508	air-line inner conductor
ML	component mount	-9509	air-line outer conductor

L suffix indicates locking Type 874 Connector.

FOR COMPLETE DETAILS, REFER TO THE GENERAL RADIO CATALOG.

General Radio 300 BAKER AVENUE, CONCORD, MASSACHUSETTS 01742

***NEW YORK**
Delaware, New Jersey, New York, Eastern Pennsylvania
380 Midland Avenue, Saddle Brook, NJ 07662
Telephone: (NJ) 201 791-8990 (NY) 212 964-2722
TWX: 710 988-2205

***BOSTON**
Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont
(SALES)
Bolton, MA 01740
Telephone: 617 646-0550
(SERVICE)
300 Baker Ave., Concord, MA 01742
Telephone: 617 369-8770 • TWX: 710 347-1051

***WASHINGTON, D.C.**
Maryland, Virginia, West Virginia, (Wash. D.C.)
15 Firstfield Road, Gaithersburg, MD 20760
Telephone: 301 948-7071 • TWX: 710 828-9741

ATLANTA
Alabama, Florida, Georgia, Mississippi, North Carolina, South Carolina, Tennessee
7 Dunwoody Park, Suite 115, Atlanta, GA 30341
Telephone: 404 457-2485, (FLA) 813 531-0148

DAYTON
Kentucky, Indiana, Michigan, Ohio, Western Pennsylvania
3300 S. Dixie Drive, Dayton, OH 45439
Telephone: 513 294-1500 • TWX: 810-459-1785

***CHICAGO**
Illinois, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, Wisconsin
9440 West Foster Avenue, Chicago, IL 60656
Telephone: 312 992-0800 • TWX: 910 221-5486

***DALLAS**
Arkansas, Colorado, Louisiana, New Mexico, Oklahoma, Texas, Wyoming
777 So. Central Expressway, Suite 1-D, Richardson, TX 75080
Telephone: 214 234-3357, (HOUSTON) 713 464-5112

***LOS ANGELES**
Arizona, Southern California, Hawaii, Nevada (Clark County only)
17361 Armstrong Avenue
Irvine Industrial Complex, Irvine, CA 92705
Telephone: 714 540-9830 • TWX: 910 595-1762

***SAN FRANCISCO**
Northern California, British Columbia, Idaho, Montana, Nevada (except Clark County), Oregon, Washington, Utah
1050 East Meadow Circle, Palo Alto, CA 94303
Telephone: 415 948-8233 • TWX: 910 373-1203
Alaska 907 279-5741

CANADA
***General Radio Canada Limited**
307 Evans Avenue, Toronto, Ontario M8Z 1K2
Telephone: 416 252-3395 • TELEX: 02-29294
Montreal 514 737-2126 • Ottawa 613 233-4237

EUROPE, AFRICA, and NEAR EAST
***General Radio Company (Overseas)**
P. O. Box, CH-8034 Zurich, Switzerland
Telephone: (01) 55 24 20 • TELEX: 845-53638

ASIA, PACIFIC, and LATIN AMERICA
General Radio International Division
Concord, Mass 01742
Cable: GENRADCO CONCORD (Mass) • TELEX: 094-594

GR COMPANIES • Grason-Stadler • Time/Data • Techware Computing Corp. GR ASSOCIATE • Micronetic Systems, Inc.

*Service Facilities

Printed in USA